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STEEL PASSENGER EQUIPMENT.*

By Charles E. Barba and Marvin Singer.

THE UNDERFRAME.—PART II.

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Arrangement of Underframe Members.

Form I.

The underframe is the great vital feature of the vehicle. Upon it depends more than upon any other members the success or failure of the design. This fact has been emphasized in the previous articles wherein consideration has been directed to the beneficent results accruing from the employment of the best engineering ability and the utilization of all the time necessary to the proper detail design of members and connections so as to produce a frame of most rational design and of structural rigidity. Should all the methods of load transferrence be dealt with in one chapter the various measures taken for detail solution would overlap to such a degree that the whole, though homogeneous, would be confusing.

The first steel cars of any account to be built in America were designed in accordance with the form of framing to be discussed in this article (Form I). The sides of the car form a girder of great depth, compared with that of the centre sills, and, as its vertical rigidity is great, it is utilized as the load carrier. Concerning this form the following paragraph quoted from our former article is pertinent:

"*Theoretically* the first form is not found in practice, as it would mean that there were no centre sills whatever, and that the whole superstructure and floor loads were transferred to the side sills and thence through the bolster to the centre-plate. The practical working out of this form, however, shows a centre sill which is weaker than the side girder, and as a result is in effect hung from the sides at intermediate points between and beyond the bolster. Then the bolster gets all its load from the side sills with the exception of the centre floor load in the immediate vicinity. The bolster with weak centre sills is then the governing feature of this form."

FIELD OF USEFULNESS.

(*a*) *Type of Service.*—The choice of the prime mover is a great factor in establishing the form of car framing most suitable for use in any specified service. This is evident from the fact that for a train of equal strength the resistibility of carrying vehicles should be on a par with the motive unit.

Lines operated by steam or electric locomotives are as a consequence not suited for equipment designed with an underframe of Form I and there is left for it but one field of usefulness in train service. Multiple unit control, which is admirably adapted to a service demanding severe schedules, frequent stops, and short headway, presents conditions suited to this type of car. To enhance the efficiency of this system of operation the cars must be of light construction and withal of a strength capable of absorbing the loads occasioned in the service or hazard of such operation. This form of car is even then only applicable to those lines where passenger and freight traffic are separated and where future conditions do not indicate any decided increase in weight or speed of the trains.

(*b*) *Types of Cars.*—From the essential and fundamental features of this form it is impossible to economically construct types of cars having the side girder cut by side entrances. It is, as a consequence, not adapted to postal, postal storage, baggage or combined cars or for side entrance passenger coaches. Various expedients, however, have been resorted to in an endeavor to carry the load over the break in continuity of the main load carrying girders. The side girder may be fish bellied at this point, or indeed may be of such a form throughout its length. This method gives a very undesirable addition of weight. For very light construction the loads can be carried across the door opening at the top by designing the posts and diagonal bracing for this purpose. This also adds more weight for a given strength. There is a possibility of locally reenforcing the centre sills in the region of the doors and then transferring the loads to the centre sills and back again to the side sills before the bolster is reached. The necessity of resorting to these expedients and the weight added being useful but locally and for a single purpose points out the conclusion that this form is not suitable for side entrance doors and that Form II should be chosen for that purpose. Here each pound added to the centre sills not only serves to help support the vertical lading but takes its share of the horizontal blows of service.

OPERATING CONDITIONS.

The studies which it is necessary to make before actual designing begins is not as much a car designer's work as that of the electrical and operating departments. This work is much simplified upon a line which is established and for which the equipment is to supersede cars now in regular service. In such a case the records of operation and accident furnish the most reliable data upon which to base the requirements to which the car designer must make his car conform. On the other hand, when a road is but contemplated and all the elements of the basic study are founded upon conjecture and problematical estimate the results are much less reliable and require more thought in being taken care of.

Character of Traffic and Schedules.—The beginning of these studies is to be found in the traffic conditions of the region feeding the common carrier and the future development of such traffic. The results or deductions are based upon the loads to be hauled, the character of the right of way and the schedule conditions. The complications arising from a mixed freight and passenger service need no consideration where Form I is to be used, as we have limited its field of usefulness to only those lines operating single cars or mutiple control passenger trains.

The loads hauled and schedule conditions govern the limitations concerning the character of the trains, the number of trains, speeds and headway, ingress and egress facilities, length of cars, and all features tending toward making for attraction to the traveling public.

The facilitation of traffic with a conservation of operating

economies is generally the primary object in electrification. There are, however, a few cases where this motive power has been required for other reasons. It follows that the cars must be constructed to further the ends of augmenting travel if the beneficent results to be secured from an increased revenue train movement by a superior type of power are to be obtained.

Truck Limitations.—Truck limitations are the governing conditions upon which maximum motor sizes are based. With the present designs of motors and wheel base governed by track conditions, with the necessity for bolster space, it is not feasible to use larger than 200 horse power per driving axle. An inspection of the clearance limits of the best commercial railway motors reveals the fact that to provide for motor leads being taken over the motor cases and leave suitable clearance there must be a minimum height of 40 inches from the rail to the under-side of the centre sills. The truck bolster is not raised higher than in ordinary trucks which produces the necessity of providing a very deep centre plate on the body of the car or on the truck. If the deep extension be down from the centre sills the motor torque acts with a long arm and the tendency to set up a bending strain in these sills is considerable. On the other hand if the centre plate extend upward from the truck bolster its tilting action is much increased over and above that due to inertia forces and the truck action is poor. This is at once evidenced in discomfort to the patrons.

Unknown Factors.—Apart from its destructive influences upon the track, the gyroscopic action of the motors has a tendency to resist the proper curving of the truck. This resistance throughout the length of the curve and upon squaring on the tangents is not only a cause of disagreeable vibrations in the car body but has its effect in the imposition of repeated strains on the underframe for which no consideration has been taken. These forces together with the inertia forces of the body are instrumental in the working of any defective riveting and ultimately throwing it askew, even if not to such a degree as to be of marked import for ordinary running, it will enhance the destructive consequences of impacts. There are many factors tending to place a complicity of strain upon the underframe for which it is impossible to secure a just approximation of the value or effect. The quality of workmanship put into the vital portions of the framing and high grade of material will assuredly take care of whatever secondary stresses arise if the loads in both vertical and horizontal planes be taken at a maximum and the specification clauses covering strengths in our previous article on the underframe be followed with the recommendations given therein. It is understood, of course, that the value of allowable end shock is not a constant and varies with the hazard of operation and inherent energy of the moving units.

As to just what strength is required it is impossible to state for all cases in general. Proper reliability must be based upon careful preliminary studies and will be found to be of a changing value.

Known Factors.—All the features noted in the preliminary investigations have a direct effect upon the underframe members. The means provided for rapid loading and unloading of passengers to reduce station stops on short headway determine the choice of platform, vestibules, door arrangement, character of seating and even length of car to a certain degree. The seating capacity together with the size of superstructure permitted by clearance diagrams gives the designer the value to be allowed for lading and a figure he dare not exceed in weight per unit of length for the complete car. This is usually found to be specified before the electrical equipment is chosen. The size of motors has been referred to as placing a lower limit on the centre sill sections. An upper limit is given to the possible height of section by the height and character of station platforms where cars use no steps or combination of straight floor and steps. This we have not found in any case to exceed 53 inches.

All the space between the lower limit of 40 inches and this top limit is not available for centre sill depth, as the flooring will take up from an inch to two inches on top of the sills.

The heavy voltages in use and the liability of serious injury from the heat which may be generated in an accident or even a local derangement of the apparatus on the car, the floor must be so designed as to resist the transmission of heat to a great degree, this provision will increase the necessary depth of flooring beyond what carrying capacity and sound deadening qualities demand. The underframe members should be constructed in detail with an eye to provision for the attachment of the apparatus which will be necessary to complete the car equipment, and in this attachment the heaviest pieces should be placed as near as possible along the centre line of the car to minimize the rolling action of the body and toward the end of the car away from the motor truck, so as to dampen the whipping action in the curving of a unit, the one end of which carries a great preponderance of weight. The question of proper insulation for the electrical apparatus has been solved in a great measure for the car designers by the electrical manufacturers insulating the pieces of apparatus within their containing cases and there need be no further consideration of that subject.

Determination of End Shock.—The cars built of this form of underframe are intended for load carrying conditions which are much similar to those provided for by the early car builders. The line of demarkation is to be noted in the necessity for centre sill construction to provide for end shocks. The character of these sills is dependent upon the probability of collision and the extremity of the destructive forces accompanying such impact. Frequency of trains and short headway, together with the character of the service, the use of the same tracks by both steam and electricity, the type of signals, condition of equipment and personnel of the service, all contribute or detract from this probability. The maximum of the destructive forces resulting from two trains endeavoring to pass each other on the same track is determined by the mass and the impinging velocity of the moving units. Evidently there is such a case that the probability of collision or wreckage is so remote and the weights and velocities so limited as to make the use of centre sills entirely unnecessary (as for example infrequent car service on trolley lines) and opposed to this condition is that of our steam trunk lines, where the probability is ever imminent and the weights and speeds a maximum.

Thus the provisions which are made for these destructive buffing strains must be capable of standing up to the data secured from a most careful study of the conditions under which the equipment will operate. Not only must these operating conditions be determined for the present, but the future should be analyzed so that the cars may be capable of providing strength and reliability for all service contingencies liable to be operative throughout its life. This can at best be only surmised and will vary much with the locality. Much can, however, be anticipated and it is always better to err on the side of increased safety. Under metropolitan operating conditions the power is much overworked at the present time, motor overheating has become a serious problem. This looks toward the use of quadruple equipment together with increased possibilities for speed and the added weight for the electrical apparatus. Then also the possibility of trunk and metropolitan lines using common tunnels or tracks to a Union station must be considered. The hazard of operation, together with the kinetic energy stored in the train, is thus a basis upon which the end shocks can be provided for in comparison with that found to hold good for steam service in the first underframe article.

Considering the features of this underframe, *i.e.*, a weak centre sill construction and rigid side girder, it is apparent that it is good only for nominal end shocks. For such service this car can be constructed lighter for a given strength than any other form. There is a point in the series of values of buffing loads for a car of given length where the economy in weight of the Forms I and II is identical, below this point the first is preferable and above it the second.

This form of underframe is hence at its best when the maximum end shocks coming upon it are not of a severity exceeding those which occur in steam service with the most careful handling. It will require but a fair sized motor train operating at good speed to produce the maximum of strain, but for purposes of illustration we shall assume to design the sectional areas re-

quired in the main members for a coach to operate under the conditions for which we have previously noted this form was most useful. That is for a road which handles passenger electric multiple control trains exclusively with schedule speeds of not more than 45 miles per hour and the maximum trains run in either express or local service to be of eight cars. The weight of these cars to be 70,000 pounds for trailers and 75,000 pounds for motors of approximately 52 feet long over platform and end sills.

In this exposition we aim to show how to use the loads to find the stresses for any car of this form, and as a consequence we shall not take into account the possibility of future developments in operation of the road. These developments would not change the character of the strains but they would alter their intensity. The degree of such change fluctuates with so many variables, as before noted, that a consideration of them would not help the discussion of how strains of this character are resisted and the stress in the members produced by such resistance. The local trains weigh more than the express trains in this service for the reason that the proportion of motor cars to trailer cars must be increased so as to obtain sufficient acceleration to make time with the very frequent stops required. The express trains travel with greater schedule speed and from an examination of such trains on existing lines we find that the kinetic energy of the two trains is about equal and that of a local excursion train of double the number of cars is not much in excess of the value of the express.

The kinetic energies of the heavy steam express trains on several prominent trunk lines operating at schedule speeds ranges anywhere from 50,000,000 to 120,000,000 foot-pounds, for which trains we have advocated a shock of 500,000 pounds static for buffing.

The kinetic energy inherent in an eight motor car train operating between 40 and 45 miles per hour is about 50,000,000 foot-pounds. The factors of weight and speed having been taken into account in both steam and electric service and the short headway in the latter making for as much possibility of operating accidents as are pregnant in the former, it would seem proper to assume that the end shocks that should be provided for in the latter case would be 5/12 of 500,000, which is about 200,000 pounds. This will illustrate exactly what is meant by the relative value of the quality of reliability, and other conditions being equal the end shocks may safely be assumed to vary from 0 to a maximum of 500,000 pounds (recommended from Lake Shore tests), and that the degree of end shock be chosen according to the ratio of kinetic energies.

ARRANGEMENT OF UNDERFRAME MEMBERS.

The diagram, Fig. 1, illustrates the disposition of the members of the framing but does not represent our ideas of detail design to stand up under the assumed end shock.

The centre sills are composed of shallow I-beams, the largest and heaviest section for the 6-inch beam being assumed. They are to be continuous from platform to platform and rest upon transverse supports to the side girder. The body end sill is the first support, next would come the bolster and between the two bolsters these supports are placed at the main posts, which in turn are spaced according to the window arrangement most convenient to the passengers and character of seating. The centre sills are then a continuous beam with 10 spans. The character of the end construction determines the values of bending stresses in the last span at each end and affects the moment in the spans contiguous to them. If the vestibule is made strong enough in the hood to act as a cantilever to help support the platform, then the end sills in this region are loaded with a uniform load, which is a maximum when the car is filling up or emptying and the platform is full of passengers. Opposed to this design is that in which the end sills get half the platform load at the platform end sill; this will increase the end bending moment in the end spans. In the former case the end span is supported and in the latter is overhanging. The supported end is the best condition and to secure it the end roof construction must be designed for good vertical rigidity and stiffness. This will in effect transfer all this load to the side girder through the body end construction and end sills. There is no other way to take care of it and provide for platform doors and steps. The diagram does not show steps, but their use is necessary for nearly all service conditions.

Centre Sill Lading.—The character of the loading which comes on these beams is a combination of, first, the uniform lading due to dead weight and passenger lading, and, second, that from the uniform load, equivalent in effect to the end shock or, if no end shock is to be provided for, the eccentric tension or compression due to the motor torque.

The determination of the reactions at the supports or transverse beams are not readily found in this type of beam (continuous) and difficulties are interposed to the finding of the shearing stresses and moments at the various sections which should be investigated. A positive check upon all the theory connected with these sills is afforded by an application of the general principles of the equation of equilibrium between external and internal forces and moments. These fundamental theories must hold as well as those for shear and moments. Stated concisely these are, *"that for any section the shearing stresses and moments are respectively equal to the algebraic loads and moments on either side of that section."* It is customary to consider the left side in calculating. Not only do these afford a check, but they are used to find the general formulæ applicable to any given case.

Each mid-span of this girder is in the same condition as if it had both of its ends overhanging and the two end spans at the platforms with but one end overhanging (for the supported condition, otherwise it would be in the position of a beam with a support in the central region).

Using a standard structural shape for the centre sills with a constant cross section and depth, the values of moment of inertia and modulus of resistance are equal throughout the sills if the supports are at the same level. This simplifies the application of the theory of three moments to the case in hand. The question as to whether it is advisable to use a light box girder of the same weight as two simple rolled shapes will depend to a great extent upon the character of the climate and atmosphere where the cars are intended to run. With the strength disposed in such a manner all the members are very thin and a corrosive atmosphere will shortly seriously impair their usefulness, since a small amount of corrosion represents such a large loss of percentage area and strength. No matter what the character of the lading or the form of the beam the theorem of "three moments" will apply to it.

THEORETICAL DISCUSSION OF CENTRE SILLS.

Continuous Beams.—The treatment of this theorem is very unsatisfactory in the majority of text and reference books upon the "Mechanics of Materials" and "Girder Design." The lack is due to the fact that with few exceptions the only beams treated are for uniform loads and lengths for all spans, so that the application to any special beam other than found therein requires the working out of a suitable formula to suit it. The derivation of the completed general formula will be found for the centre sill assumed, and the remainder written by analogy to fit each span.

The method of the solution is to first find the equation of the elastic curves for any section and its adjacent span which multiplied by the product of the coefficient of elasticity into the moment of inertia will be a measure of the bending moment. These two differential equations when integrated once and the constants of integration determined represent the slope of the tangent to the elastic curve. Now since the curves have been found for two adjacent spans it follows that over the point of support between the spans the curves must have a common tangent. The next step is to evaluate the tangent equations for the ordinates of this point of tangency and equate the two equations which are now identical and the solution of this resulting equation gives a result showing the relation between the three moments, the two span lengths and the loading upon each length. The problem is complicated somewhat because the equations contain

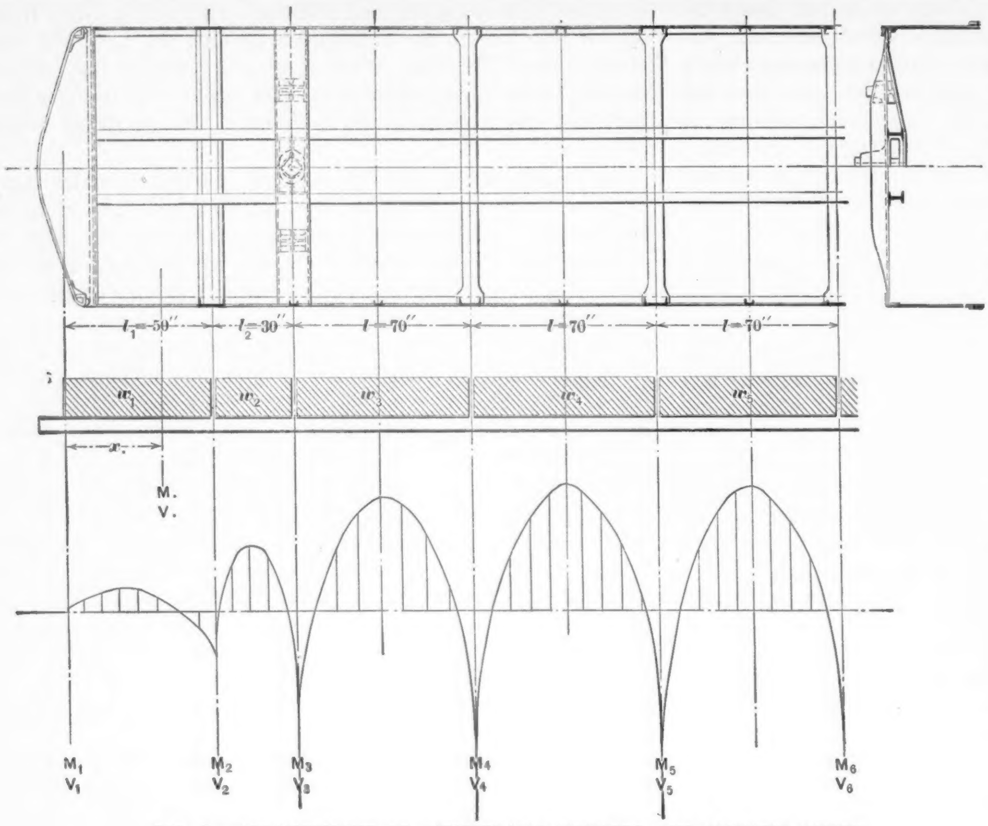


FIG. I.—ARRANGEMENT OF UNDERFRAME MEMBERS AND MOMENT CURVES.

expressions of the vertical shearing stress at the supports and it becomes necessary to find the moments at the supports to eliminate it in the tangent formula.

Consider the first two spans at the left end of the diagram. The moments, reactions, shears, lengths, and weights are designated. For any curve of bending, the general formula expressing the relation between the bending moment, physical properties and disposition of the material and curve is

$$\frac{d^2y}{dx^2} = \frac{M}{EI}$$

or

$$EI \frac{d^2y}{dx^2} = M \quad \ldots\ldots 1.$$

Now for any section at distance x from the end, the general law of moments will give

$$EI \frac{d^2y}{dx^2} = M = M_1 + V_1x - \tfrac{1}{2}w_1x^2 \quad \ldots\ldots 2.$$

This equation upon being integrated and the constants of integration being found from the relations that $y = o$ when $x = l$, there will result

$$24EI \frac{d^2y}{dx^2} = 12M_1(2x - l_1) + 4V_1(3x^2 - l_1^2) - [w_1(4x^3 - l_1^3)] \quad \ldots\ldots 3.$$

By analogy we can write for the second span

$$24EI \frac{dy}{dx} = 12M_2(2x - l_2) + 4V_2(3x^2 - l^2_2) - w_2(4x^3 - l_2^3) \quad \ldots\ldots 4.$$

These are the two tangent slopes which must be identical when $x = l$, in the first case and when $x = o$ in the second. This substitution having been made (3) becomes

$$24EI \frac{dy}{dx} = 12M_1l_1 + 8V_1l_1^2 - 3w_1l_1^3 \quad \ldots\ldots 5.$$

and (4) becomes

$$-24EI \frac{dy}{dx} = -12M_2l_2 - 4V_2l_2^2 + w_2l_2^3 \quad \ldots\ldots 6.$$

The signs have been changed, due to the difference in character of the moments, but the numerical value remains the same.

These equations must be evaluated for the shears V_1 and V_2 before they are in shape to use, as we wish. The general theory of shears gives the result for shear v at any section x.

$$V = V_1 - w_1x \quad \ldots\ldots 7.$$

V_1, from the above theory, represents the algebraic sum of all the loads on the left of the section. These loads have a moment about the section x depending upon how far the graphical resultant of those loads is removed from x.

V_1 is the resultant and the arm of its action to the left of the point of support can be assumed to be x_1, then the moment of these loads about x is

$$V_1(x_1 + x)$$

$$M_x = V_1(x_1 + x) - w_1x\tfrac{1}{2}x$$

$$= V_1x_1 + V_1x - \frac{w_1x^2}{2} \quad \ldots\ldots 8.$$

Now from definition $V_1\,x_1$ is the value of the moment at left support and as such is equal to M, shown in the diagram, hence formula (8) becomes

$$M_x = M_1 + V_1x - \tfrac{1}{2}w_1x^2 \quad \ldots\ldots 9.$$

This shows that to find M_x it is necessary to know V_1 and M_1. Now suppose x to be taken equal to l, which will cause M_x to equal M_2 and formula (9) becomes

$$M_2 = M_1 + V_1l_1 - \tfrac{1}{2}w_1l_1^2 \quad \ldots\ldots 10.$$

This when transposed gives a value of

$$V_1l_1 = M_2 - M_1 + \tfrac{1}{2}w_1l_1^2 \quad \ldots\ldots 11.$$

By analogy the values of V_n may be written

$$V_n = \frac{M_{n+1} - M_n + \tfrac{1}{2}w_nl_n^2}{l_n} \quad \ldots\ldots 12.$$

Substituting values of V_1 in equation (5) and V_2 in equation (6) and equating the results there is found

$$M_1l_1 + 2M_2(l_1 + l_2) + M_3l_3 = \tfrac{1}{4}w_1l_1^3 - \tfrac{1}{4}w_2l_2^3 \quad \ldots\ldots 13.$$

which in its general form for any span (n) is

$$M_nl_n + 2M_{n+1}(l_n + l_{n+1}) + M_{n+2}l_{n+2} = \frac{w_n}{4} \cdot l_n^3 + \frac{w_{n+1}}{4} l^3_{n+1} \quad \ldots 14.$$

These formula show how the bending moment at any support is connected with those on either side of it.

The bending moments at the supports are thus determined, it remains to find that for the middle of the span. Considering equation (9) written in a general form for span (n) from left end and x to be taken for the middle ordinate or $x = \frac{l_n}{2}$ then

$$M_x = M_n + V_n \frac{l_n}{2} - \frac{w_n}{4} l_n^2 \quad \ldots\ldots 15.$$

Now from (12) substitute the value of V_n and simplify when there will result

$$M_x = \frac{M_n + M_{n+1}}{2} \quad \ldots\ldots 16.$$

which denotes that at the middle of any span the bending moment is a mean of that at either end.

In the diagram there are 10 spans and 11 supports with 9 unknown moments. Nine equations can be written by analogy from formula (14), but only the first five of them are necessary for solving this problem, since the following relations between the quantities hold from the construction. These are $l_3 = l_4 = l_5 = l_6 = l_7 = l_8 = l_9 = l$. $l_{10} = l_2$ and $l_{11} = l_1$.

$M_1 = M_{11} = O$

$M_2 = M_{10}$

$M_3 = M_9$

$M_4 = M_8$

$M_5 = M_7$ and all values of w are equal.

(*b*) *Struts.*— The design of columns rests on a much less rational basis than beams. Euler's formula is theoretically correct in giving the load which causes rupture by lateral binding, but is only true for columns where the slenderness ratio is large. Merri-

man cites Rankine's formula as the peer of any of the column formulæ which have been developed to investigate the action of columns when stressed within the elastic limit. This column formula

$$S = \frac{P}{a}\left[1 + \vartheta\left(\frac{l}{r}\right)^2\right]$$

when solved for values of

$P = 200{,}000$ pounds

$a = 2 \times 5.07 = 10.14$ sq. inches

$\vartheta = \frac{4}{25000}$

$r = 2 \times 2.27 = 4.54$ inches

will give a value of S, which is beyond the ultimate strength of the centre sill beams. This is the condition that would have to be provided for if the connection between the centre sills and the side sills were not perfectly rigid and stronger than the beams themselves in their members. Hence the method of using weak sills with such an end shock is to reduce the slenderness ratio and approximate as closely as possible to the condition of a series of short struts or even compression pieces. To do this we shall consider the connections as we have said they must be and solve for struts of lengths 70 inches, 50 inches and 30 inches.

The stress is a combination of the direct and bending stresses. This portion of the stress due to bending, which is $\vartheta \frac{l^2}{r^2}$, we propose to use as a measure of uniform load which produces a bending action in the centre sills at right angles to the uniform lading of the car body. This operation is necessary to secure a just appreciation of the forces which come on the side sills in a horizontal plane. This condition holds when the transverse supports are firm in a combination of either tension or compression and flexural stresses and the centre sills have their greatest least radius of gyration about a vertical axis, as is true in this case.

(To be continued.)

INSTALLATION OF DR. W. F. M. GOSS.

The formal exercises incident to the installation of Dr. W. F. M. Goss as Dean of the College of Engineering of the University of Illinois, occurred February 5 in connection with the formal opening of the graduate school of the University. The exercises included two sessions and a tour of inspection through the laboratories.

The morning session began with a brief address by the president of the University, Dr. Edmund J. James, introducing the chairman of the session, Prof. James M. White. Addresses were delivered by Prof. Ira O. Baker, describing some significant events in the development of the college, with which he has been identified for more than thirty years. Mr. William L. Abbott, president of the Board of Trustees, briefly discussed the standing of the technical graduate in the engineering profession. Following this the formal installation address of Dr. Goss entitled the "State College of Engineering," was delivered.

The afternoon session included an address by Mr. Robert W. Hunt on "The Value of Engineering Research," and an address by Mr. Williard A. Smith, on the "Need of Graduate Courses in Engineering."

Between the sessions a trip of inspection through the several laboratories took place. Special interest was shown by the visitors in the electric test car; the railway dynamometer car, and the 600,000-lb. testing machine for work on reinforced concrete, which are installed in these laboratories. A large number of guests were present, including representatives of all the more important educational and scientific societies and technical journals.

MARCH MEETING OF THE A. S. M. E.—At the next regular monthly meeting, to be held in New York on the evening of March 10, a paper on the "Steam Path of the Steam Turbine" will be presented by Dr. Charles P. Steinmetz.

LOCOMOTIVE SMOKE STACKS.

BY W. E. JOHNSTON.

The Master Mechanics' tests on exhaust pipes and nozzles made at Purdue in 1896 showed the form of the exhaust jet for a 4¼" nozzle very clearly and if further tests were made with nozzles of different diameters, it is reasonable to suppose that the form of the jet from all nozzles of the same type would be similar and that the diameter of the jet at any point would be proportional to the diameter of the nozzle. Also, since the diameter of the jet increases in a definite manner as it leaves the nozzle, some expression can be derived to show the diameter of the jet at any point. Further, since the jet produces the vacuum in the smoke box, it should be possible to derive a formula for stack diameter, based on the nozzle diameter and the distance from nozzle to the choke of a taper stack or some corresponding point in a straight stack.

A comparison of a few boilers of recent design for Mikado, Consolidation, Pacific, American and six-wheel switch engines shows that the Master Mechanics' formulæ will give quite different results from one based on nozzle diameter and distance from nozzle to stack.

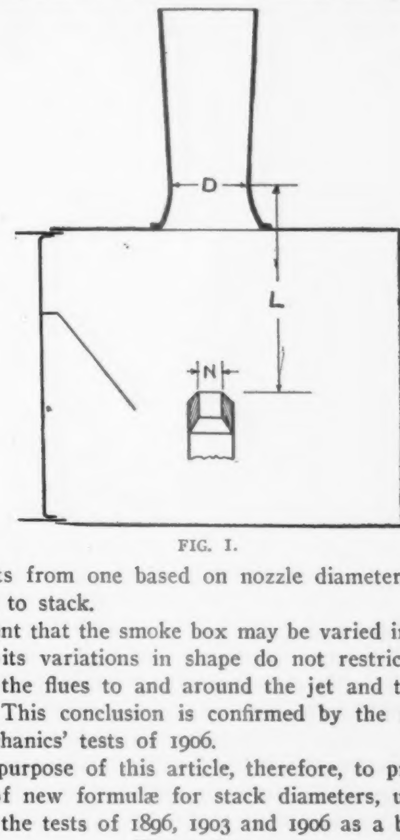


FIG. I.

It is evident that the smoke box may be varied in any manner, so long as its variations in shape do not restrict the flow of gases from the flues to and around the jet and to the base of the stack. This conclusion is confirmed by the results of the Master Mechanics' tests of 1906.

It is the purpose of this article, therefore, to present the development of new formulæ for stack diameters, using the data obtained in the tests of 1896, 1903 and 1906 as a basis.

TAPER STACKS.

The tests of 1896, in addition to showing the form of the jet, showed that the best distance for a 4¼" nozzle from the choke of a 14" taper stack was about 47", using a draft pipe. The best results for the 1903 tests are shown in Table I. and Fig. 1, using the same references for nozzles as in the Master Mechanics' Committee's report.

TABLE I.

Nozzle.	"D" Best Results.	L.	$\sqrt{L.}$	$\frac{D}{4\frac{1}{4}\sqrt{L.}}$
1	14¾"	55"	7.42	.47
2	13¾"	50"	7.07	.46
3	13½"	45"	6.71	.47
4	12¼"	40"	6.32	.46
5	11¾"	35"	5.92	.47
6	11¼"	30"	5.50	.48
7	10"	25"	5.00	.47
Average				.47

By trial, it was found that the diameter of the best stack varied at a less rate than the distance "L" and that this variation was practically proportional to the square root of this distance; that is, $\frac{D}{4\frac{1}{4}\sqrt{L}}$ is constant. Assuming that the diameter of the best stack is proportional to the diameter of the nozzle, the

equation using the average value of $\dfrac{D}{4\frac{1}{4}\sqrt{L}}$ is $D = .47\ N\ \sqrt{L}$.

Where N = diameter of nozzle ($4\frac{1}{4}''$ in these tests).
L = distance from nozzle to choke of stack in inches.
D = diameter of stack.

The results of the 1906 tests were not plotted in the diagrams included in the report of the Master Mechanics' Committee to show the variations in diameter of the best stack with variations in the distance from nozzle to choke. Diagrams Figs. 2 to 9 have, therefore, been prepared, showing the results of the tests with 3lb, 4lb and 5lb back pressure as far as shown in the

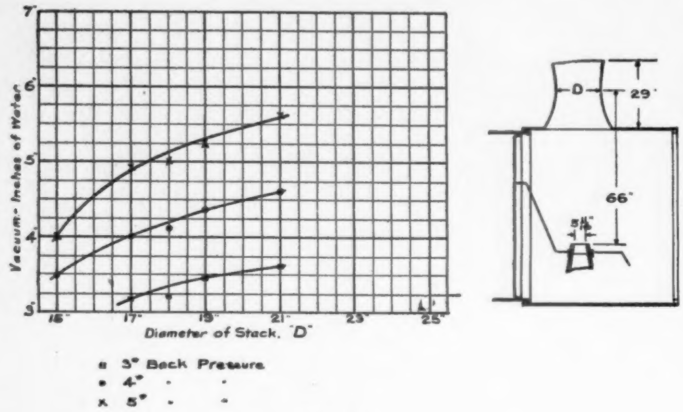


FIG. 2.

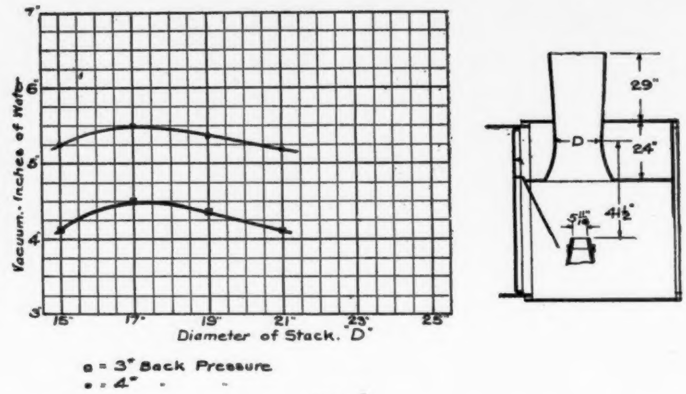


FIG. 6.

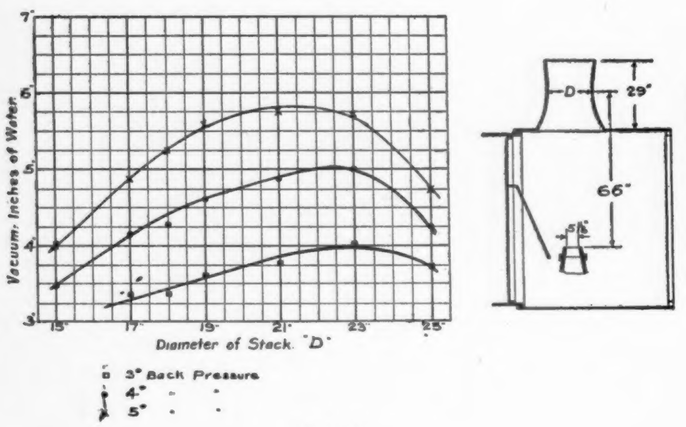


FIG. 3.

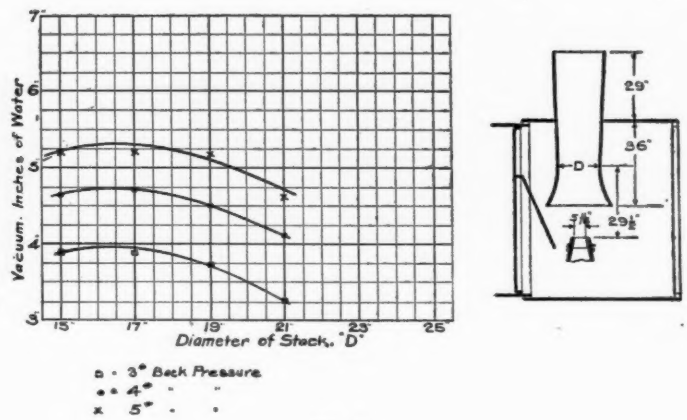


FIG. 7.

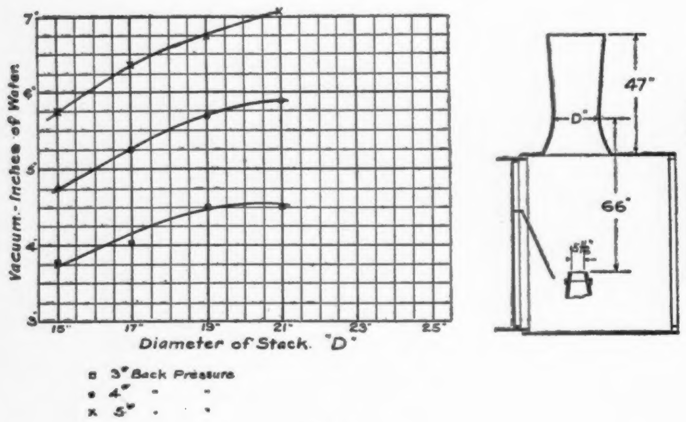


FIG. 4.

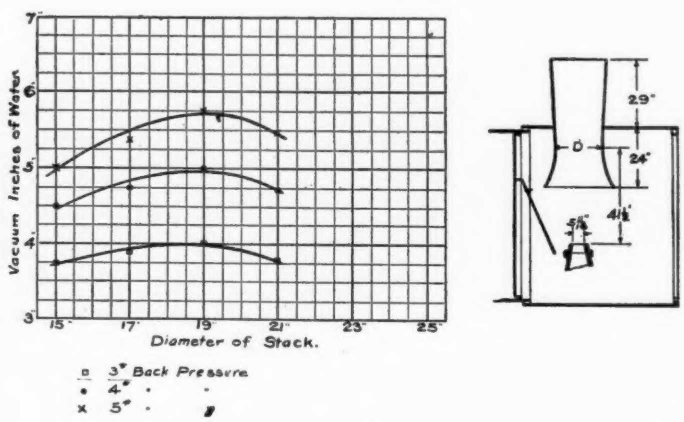


FIG. 8.

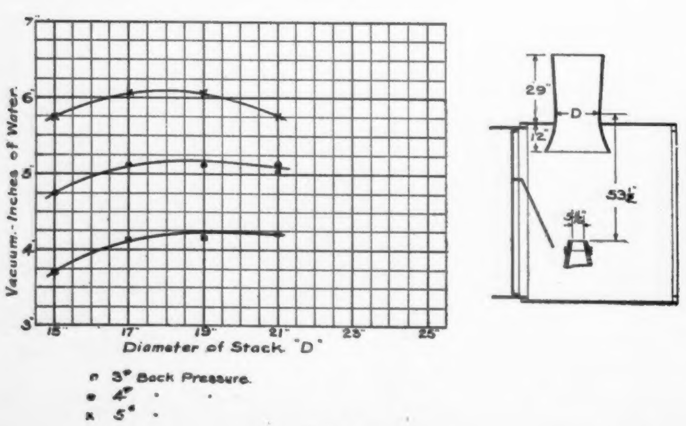


FIG. 5.

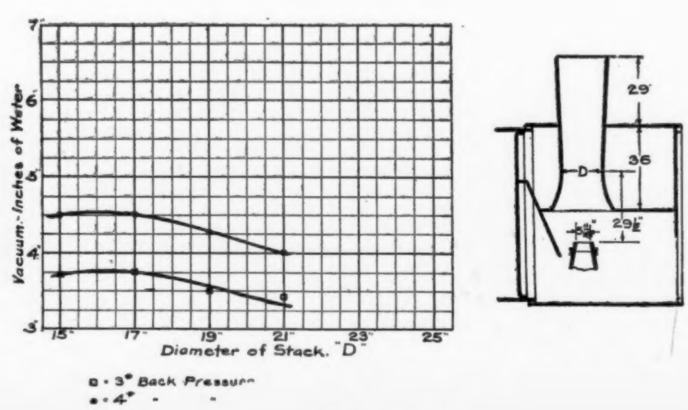


FIG. 9.

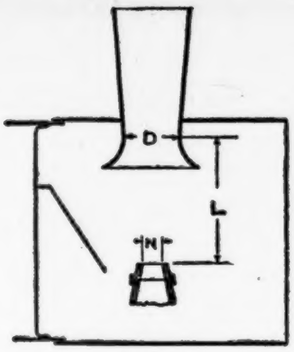


FIG. 10.

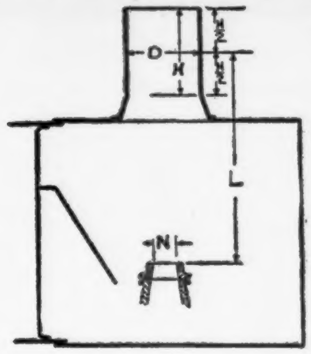


FIG. 11.

report for plain front ends, Series No. 2 to No. 9.

From these diagrams Table II. and Fig. 10 have been taken.

TABLE II.

Series.	"D" Best Results.	L.	L.	$\frac{D}{5\ 11/16 \sqrt{L}}$.
2	Greater than 21"	66"		
3	23"	66"	8.12	.497
4	Greater than 21"	66"		
5	19"	53½"	7.32	.456
6	19"	41½"	6.44	.518
7	16"	29½"	5.43	.517
8	17"	41½"	6.44	.464
9	16"	29½"	5.43	.517
Average	....			.49

The equation for these tests is then $D = .49\ N \sqrt{L}$, derived in the same manner as for the 1903 tests. Referring again to the tests of 1896, the equation derived similarly is $D = .48 \sqrt{L}$. The larger constant in the formula for the 1906 tests is probably due to the form of the nozzle. The 1903 nozzle is like Style "X," shown in the 1896 report, while the 1906 nozzle is like Style "Y"; Style "X," as stated in the 1896 report, gives less spread to the jet and would, therefore, require a slightly smaller stack than Style "Y."

The close agreement between the equations for the three years would seem to be sufficient proof of the reliability of the formula for general use.

Fig. 12 shows a diagram for conveniently finding the diameter of choke for taper stacks, based on the equation $D = .49\ N \sqrt{L}$.

STRAIGHT STACKS.

It is reasonable to suppose that the formula for straight stacks would be similar to that for taper stacks. In this case there is no definite place corresponding to the choke of a taper stack which may be taken as a measuring point.

Table III. and Fig. 11, however, show the results for the tests of 1903, obtained by taking "L" to the middle of the straight portion of the straight stacks and would seem to indicate that the formula $D = .49 \sqrt{L}$ would give satisfactory results for straight stacks also.

TABLE III.

Length of Stack.	Nozzle Number.	"D" Best Results.	L.	$\sqrt{L}$.	$\frac{D}{4\frac{1}{4} \sqrt{L}}$.
	1	Greater than 15¾"	60		
	2	15¾"	55	7.42	.500
	3	14¼"	50	7.07	.474
26½"	4	13¾"	45	6.71	.483
	5	13¼"	40	6.32	.493
	6	12¼"	35	5.92	.487
	7	11¾"	30	5.48	.503
	1	Greater than 15¾"	65		
	2	Greater than 15¾"	60		
	3	15¾"	55	7.42	.500
36½"	4	14¾"	50	7.07	.491
	5	14¼"	45	6.71	.500
	6	13¼"	40	6.32	.493
	7	11¾"	35	5.92	.467
	1	Greater than 15¾"	70		
	2	Greater than 15¾"	65		
	3	Greater than 15¾"	60		
46½"	4	15¼"	55	7.42	.484
	5	14¾"	50	7.07	.491
	6	14¼"	45	6.71	.500
	7	13¼"	40	6.32	.493
	1	Greater than 15¾"	75		
	2	Greater than 15¾"	70		
	3	Greater than 15¾"	65		
56½"	4	15¾"	60	7.75	.478
	5	15¾"	55	7.42	.500
	6	14¾"	50	7.07	.491
	7	13¾"	45	6.71	.483
Average	....				.49

Inasmuch as the variation in diameter of the stack is from two and a half to four times the variation in nozzle diameter, considerable care will be necessary in using this formula on new designs to determine the diameter of the nozzle reasonably close in advance for the particular conditions under which the engine is to operate. On old engines, the problem is simple, of course, as the size of the nozzle can be measured readily and the stack diameter can be taken from Fig. 12.

It should be noted that this formula is based on front ends without draft pipes and, therefore, as determined by the Master Mechanics' Committee in 1906, will give larger stack diameters than for front ends with draft pipes, this being in accordance with their report, that the larger stack without draft pipes gave the most satisfactory results.

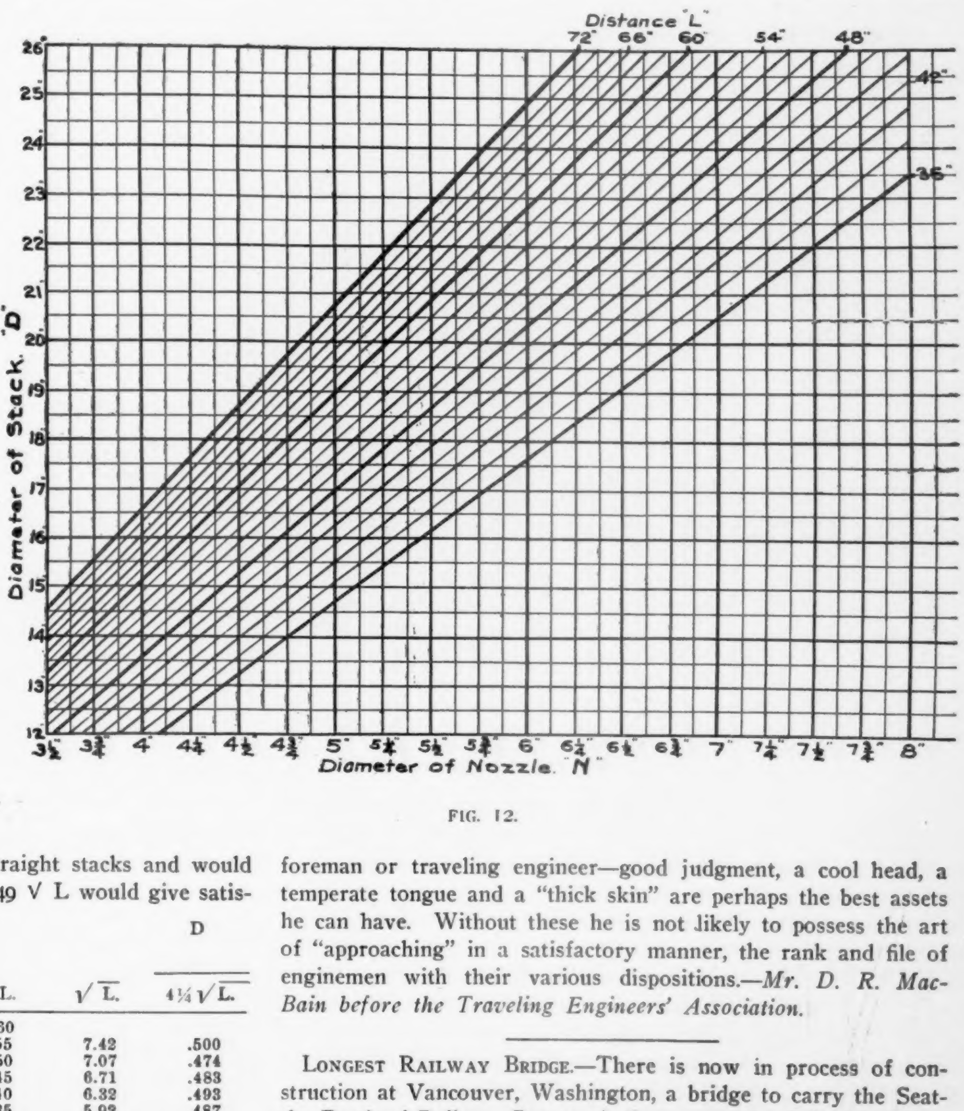
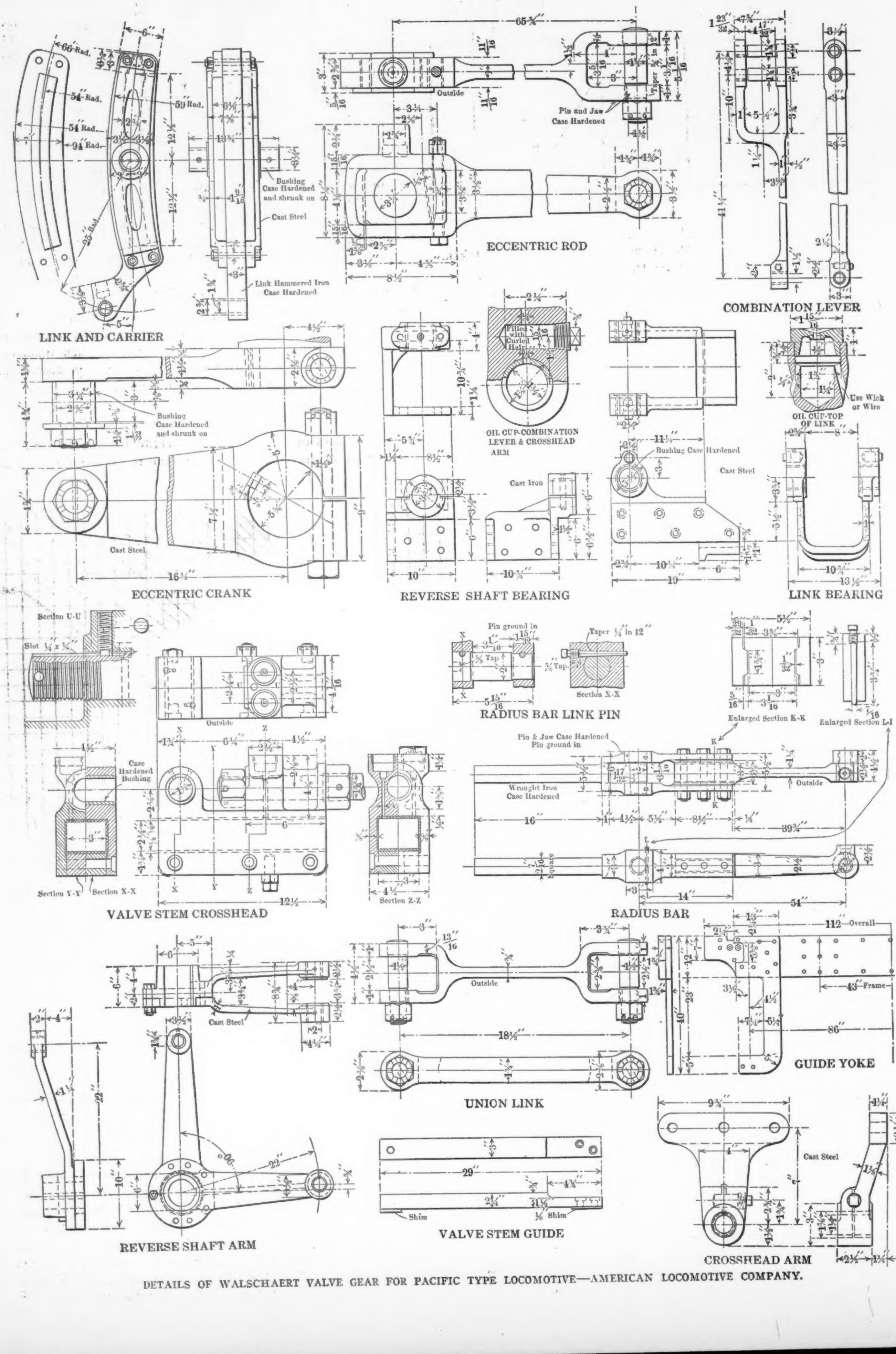


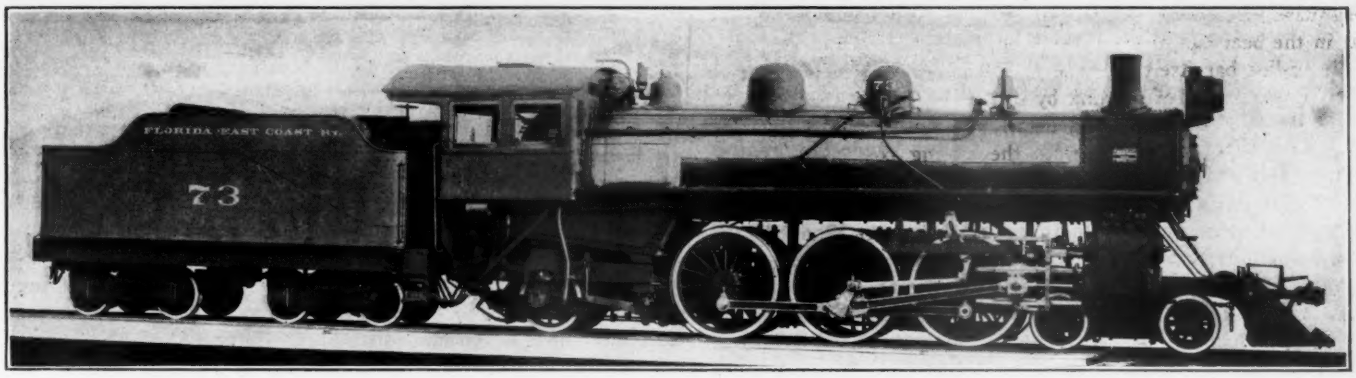
FIG. 12.

REQUIREMENTS OF SUCCESSFUL TRAVELING ENGINEERS.—Success and skill as enginemen are not all that is essential in a road foreman or traveling engineer—good judgment, a cool head, a temperate tongue and a "thick skin" are perhaps the best assets he can have. Without these he is not likely to possess the art of "approaching" in a satisfactory manner, the rank and file of enginemen with their various dispositions.—*Mr. D. R. MacBain before the Traveling Engineers' Association.*

LONGEST RAILWAY BRIDGE.—There is now in process of construction at Vancouver, Washington, a bridge to carry the Seattle, Portland Railway Company's line across the Columbia River, which when completed will have the distinction of being the longest bridge of its class in the world. Its total length will be 1½ miles and its width will be about 35 ft., carrying a double track. The completed bridge will comprise 47 spans. A draw span, 450 ft. long, is provided in the centre of the river.



DETAILS OF WALSCHAERT VALVE GEAR FOR PACIFIC TYPE LOCOMOTIVE—AMERICAN LOCOMOTIVE COMPANY.



PACIFIC TYPE LOCOMOTIVE WITH WALSCHAERT VALVE GEAR.

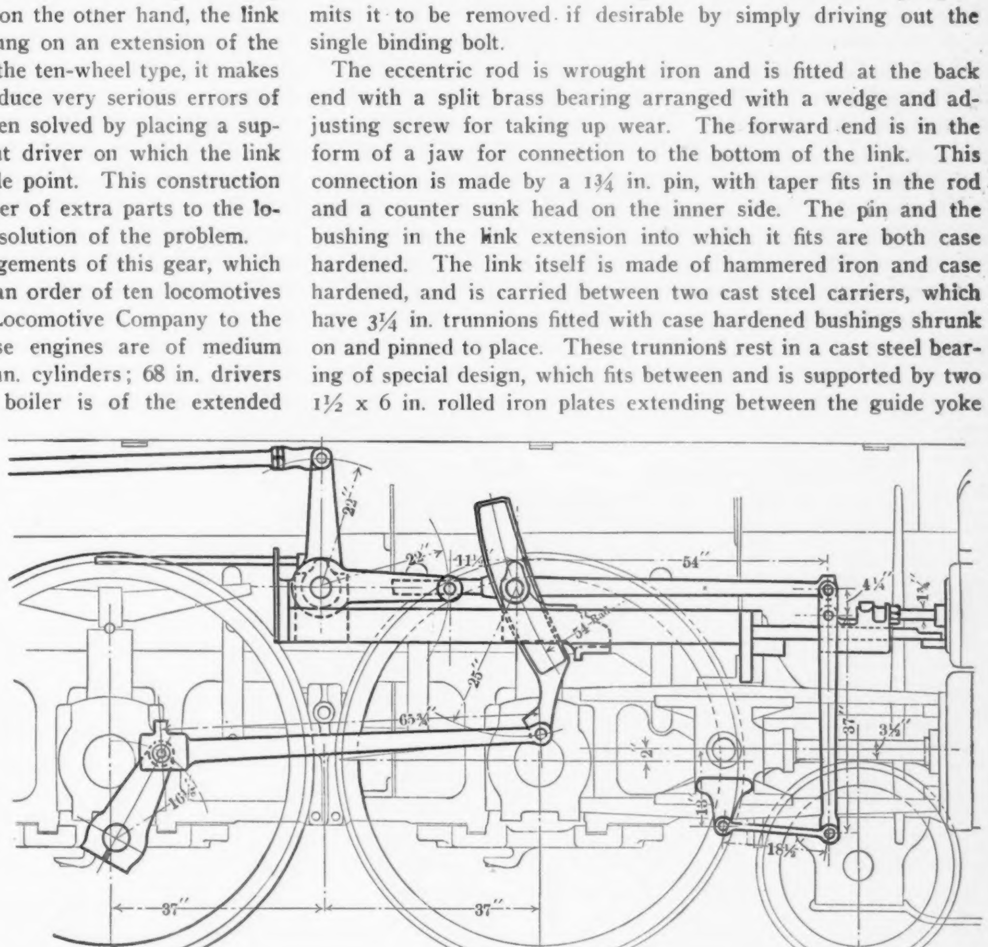
WALSCHAERT VALVE GEAR FOR PACIFIC TYPE LOCOMOTIVE.

The application of the Walschaert type of valve gear to a Pacific type locomotive presents difficulties not encountered with other wheel arrangements. This, of course, is due to the proximity of the front driving wheel to the cylinder, necessitating the placing of the guide yoke very far forward and preventing its use as a support for the link. If, on the other hand, the link is placed back of the driver, being hung on an extension of the frame cross tie, as is often done with the ten-wheel type, it makes the eccentric rod so short as to introduce very serious errors of angularity. These difficulties have been solved by placing a supplementary frame outside of the front driver on which the link can be supported at the most desirable point. This construction adds considerable weight and a number of extra parts to the locomotive, but is practically the only solution of the problem.

One of the simplest and best arrangements of this gear, which has come to our notice, is found on an order of ten locomotives recently delivered by the American Locomotive Company to the Florida East Coast Railroad. These engines are of medium weight, Pacific type, having 20 x 26 in. cylinders; 68 in. drivers and weigh 196,000 lbs. total. The boiler is of the extended wagon top type, measuring 62¼ in. diameter at the front end, has a total heating surface of 2,571 sq. ft. and carries a steam pressure of 200 lbs. The design of the engine is in general the same as other locomotives of this type built by this company, many of which have been illustrated in these columns, and outside of the valve gear will be given no special mention. The double check valve on the top of the front barrel sheet is of the Phillips design, and was described on page 27 of the January issue of this journal. The general dimensions and ratios are as shown in the table at the end of this article.

The valve gear, as is always desirable, is practically all in one vertical plane, there being but 2½ in. difference between the center of the pin on the eccentric crank and the valve stem; 1½ in. of this is in an off-set in the eccentric rod and 1 in. is obtained at the connection of the radius bar to the combination lever. The valve chamber is thrown 4 in. outside the center of the cylinders, which presents no objection other than the increase in the weight of the cylinder casting and slightly longer steam passage, provided the clearance limits are not exceeded.

The illustrations on the opposite page show the detailed design of the more important parts of the gear. The eccentric crank is of cast steel and fits over a 5⅝ in. diameter extension of the main crank pin, to which it is secured by a 1½ in. binding bolt.



WALSCHAERT VALVE GEAR ON PACIFIC TYPE LOCOMOTIVE.

The crank is split at the back and a clearance of ¼ in. allowed, so that it can be drawn tightly to a bearing by means of the bolt. The crank is maintained in its setting by a ¾ x 1 in. key and by the binding bolt fitting into a recess in the main pin, as is shown in the drawing. The pin on the end of the crank is 3¼ in. diameter, and is provided with a case hardened bushing shrunk into place, which forms a bearing for the eccentric rod brass. This method of fastening the crank to the main pin permits it to be removed if desirable by simply driving out the single binding bolt.

The eccentric rod is wrought iron and is fitted at the back end with a split brass bearing arranged with a wedge and adjusting screw for taking up wear. The forward end is in the form of a jaw for connection to the bottom of the link. This connection is made by a 1¾ in. pin, with taper fits in the rod and a counter sunk head on the inner side. The pin and the bushing in the link extension into which it fits are both case hardened. The link itself is made of hammered iron and case hardened, and is carried between two cast steel carriers, which have 3¼ in. trunnions fitted with case hardened bushings shrunk on and pinned to place. These trunnions rest in a cast steel bearing of special design, which fits between and is supported by two 1½ x 6 in. rolled iron plates extending between the guide yoke and the extension of a special frame cross tie located between the first and second pair of drivers. These plates are set at 12¼ in. centers and form a very rigid support for all of the main members of the gear.

The reverse shaft is carried in bearings fastened between and to these plates at their connection to the frame cross tie. This bearing, which is shown in detail, is fitted with a cap held in place by two bolts, permitting the easy removal of the shaft. The reverse shaft arms are of cast steel in two parts, so constructed that the outer section of the arm can be removed without disturbing the shaft or inner arm. A block, having a sliding fit on

the square end of the radius bar, is fitted with trunnions which seat in the bearings of the reverse lever arm.

The radius bar itself is made in two parts, which are secured together just ahead of the link by three 1 in. bolts. This connection is specially designed, and details are shown in the illustration. The after section includes the sliding connection to the reverse shaft and the pin connecting to the link block. The details of this pin are also shown in the illustration.

The valve stem connects to the cast steel cross head, sliding upon a single bar guide, 2¼ x 3 in. in section, supported between the valve chamber head and guide yoke. The combination lever spans this cross head and its guide and is connected to it by a 1¾ in. pin, which is case hardened and runs in a case hardened bearing in the cross head. The union link is forked at both ends and is shown in detail in the illustration.

The provision for lubrication throughout the whole gear is exceptionally complete, as is also the provision for minimizing the wear at all bearing points. This has been done by the practically universal use of case hardened pins which fit in case hardened seats and run in case hardened bushings.

The general dimensions and other data of these locomotives are shown in the following table:

GENERAL DATA.	
Gauge	4 ft. 8½ in.
Service	Passenger
Fuel	Bitum. Coal
Tractive effort	26,000 lbs.
Weight in working order	196,000 lbs.
Weight on drivers	122,500 lbs.
Weight of engine and tender in working order	319,600 lbs.
Wheel base, driving	12 ft. 4 in.
Wheel base, total	32 ft. 7 in.
Wheel base, engine and tender	60 ft. 2 in.
RATIOS.	
Weight on drivers ÷ tractive effort	4.70
Total weight ÷ tractive effort	7.50
Tractive effort × diam. drivers ÷ heating surface	685.00
Total heating surface ÷ grate area	55.20
Firebox heating surface ÷ total heating surface, per cent	6.25
Weight on drivers ÷ total heating surface	47.80
Total weight ÷ total heating surface	76.10
Volume both cylinders, cu. ft.	9.50
Total heating surface ÷ vol. cylinders	270.00
Grate area ÷ vol. cylinders	4.90
CYLINDERS.	
Kind	Simple
Diameter and stroke	20 x 26 in.
VALVES.	
Kind	Piston
Greatest travel	6 in.
Outside lap	1⅛ in.
Inside clearance	1/16 in.
Lead, constant	3/16 in.
WHEELS.	
Driving, diameter over tires	68 in.
Driving, thickness of tires	3 in.
Driving journals, main, diameter and length	9 x 12 in.
Driving journals, others, diameter and length	8½ x 12 in.
Engine truck wheels, diameter	33 in.
Engine truck, journals	5½ x 10 in.
Trailing truck wheels, diameter	42 in.
Trailing truck, journals	8 x 14 in.
BOILER.	
Style	E. W. T.
Working pressure	200 lbs.
Outside diameter of first ring	62¼ in.
Firebox, length and width	96 x 70 in.
Firebox plates, thickness	⅜ & ½ in.
Firebox, water space	F-5, S & B-4½ in.
Tubes, number and outside diameter	250—2 in.
Tubes, length	18 ft. 6 in.
Heating surface, tubes	2,410.7 sq. ft.
Heating surface, firebox	160.4 sq. ft.
Heating surface, total	2,571.1 sq. ft.
Grate area	46.8 sq. ft.
Smokestack, diameter	16 in.
Smokestack, height above rail	14 ft. 3⅝ in.
TENDER.	
Tank	Water Bottom
Frame	13 in. channels
Wheels, diameter	33 in.
Journals, diameter and length	5½ x 10 in.
Water capacity	6,000 gals.
Coal capacity	10 tons

Greatest Lumber Cut.—The Forestry Service of the U. S. Department of Agriculture reports that more lumber was cut in the U. S. last year than in any other year in its history. A total of 37,550,736 board feet, which has a mill value of $621,151,388, was produced. In addition there were nearly 12,000,000,000 shingles, valued at $24,000,000, and nearly 4,000,000,000 laths, valued at $11,500,000. An investigation of circular No. 122, giving the different kinds of lumber produced, shows very clearly the passing of white pine and oak. Since 1899 the cut of the former has fallen off more than 40 per cent., and white oak has fallen off more than 36 per cent. Yellow pine leads all other woods in the amount cut, with Douglass fir as a second. Since 1899 the average increase in the price of lumber has been about 49 per cent.

HANDLING LOCOMOTIVE SUPPLIES.*

By E. Fish Ensie.

Part II.
Accounting.

Between reduced rates from adverse legislation, and the increased prices demanded for labor and material, railway managements are facing a condition which calls for a greater economy of operation per dollar earned, if the rapidly narrowing margin of profit is to be stayed and brought back even to the figures attained in the immediate past. If the return on the capital in railroad property is to approach a figure equivalent to the returns on investment in other commercial securities, a still greater effort must be made to use the facilities, equipment, and means for the carrying on of business, to the utmost limit of efficiency.

By reference to Moody's Manual for 1907, it will be found that of 674 "Independent" operating steam railroads in the United States, and of 57 large "Systems" (comprising 688 subsidiary companies), the former comprise not quite 11 per cent., and the latter nearly 90 per cent. of the railway mileage, thus showing to how great an extent consolidation and centralization of railway management has taken place in this country. We cannot hope, nor is it desirable, to return to the old conditions when the roads were so small that officer and man dealt personally with each other; for these personal relations of the past, now gone for ever, we must substitute an artificial means of keeping those in the saddle of responsibility in touch with the details of actual conditions, so that, having an intelligent view of the practices of the present, these responsible officers can lay down broader formulæ for the future.

Let us admit that the conditions of railroading have made operative costs so high that now the margin of net earnings is scarcely guaranteeing a proper return on capital investment (forcing one good sized road into receiver's hands); let us, however, remedy this condition, not by cutting off improvements under way, and necessary for economical operation of the future, but by looking to the efficiency and economy of organization and operation, with the view to reducing operative expense per unit of operation by the application of modern methods, and by the judicious stimulation of co-operative interest on the part of employees.

Let us look at our problem in this way: although we should no doubt continue to add to facilities and equipment, in order to prepare ourselves for the traffic of the future, when now we find capital for these additions hard to raise, hard to wring from dividends, we must use the equipment and facilities more efficiently and fully (a form of capitalizing earning capacity), and this applies whether we consider track in reference to its traffic carrying condition, or the investment in the supplies carried on locomotives.

The instrument, that combines the function of a telescope of inspection with a rifle of attack, for the modern officer of supervision, is a systematic method of accounting, designed to reflect actual detail operations. The basis for such an accounting system must be the prescribed Interstate Commerce Commission classification. If we are to have any intelligent supervision of locomotive supplies at all, we must have account of them properly and adequately rendered, and we must take as the basis of these accounts that portion of the Interstate Commerce Commission classification which relates to the articles comprising these supplies, and the costs of handling them.

These portions of the official classification are quoted verbatim in the following and those portions of special note in connection with this subject are italicized.

(The following, under the head of "Equipment," is taken from pages 23 and 24 of the "Classification of Expenditures for Road and Equipment, as Prescribed by the Interstate Commerce Commission, in Accordance with Section 20 of The Act to Regulate Commerce First Revised Edition"):

37. STEAM LOCOMOTIVES.—To this account should be charged the cost of steam locomotives and tenders, *including all appurtenances, furniture, and fixtures necessary to equip them for service*, purchased or built

* Continued from page 11 of the January, 1908, issue.

at the company's shops, including cost of transportation and setting up after receipt from builders.

38. ELECTRIC LOCOMOTIVES.—To this account should be charged the cost of electric locomotives, *including all appurtenances, furniture, and fixtures necessary to equip them for service*, purchased or built at the company's shops, including cost of transportation and setting up after receipt from builders.

(The following extracts are taken from the "Classification of Operating Expenses, as Prescribed by the Interstate Commerce Commission, in Accordance with Section 20 of The Act to Regulate Commerce, "Third Revised Issue"):

[*From Page 18.*]

Account.		Page.
II.	MAINTENANCE OF EQUIPMENT—	
[29]	Steam Locomotives—Repairs	42

[*From Page 19.*]

IV.	TRANSPORTATION EXPENSES—	
[78]	Enginehouse Expenses—Yard	68
[82]	Other Supplies for Yard Locomotives	69
[87]	Enginehouse Expenses—Road	71
[91]	Other Supplies for Road Locomotives	73

(Numbers in brackets refer to consecutive arrangement of Primary Accounts as listed on pages 17 to 20, inclusive, of the "Classification of Operating Expenses as Prescribed by the Interstate Commerce Commission in Accordance with Section 20 of The Act to Regulate Commerce—"Third Revised Issue—1907.")

[*From Pages 42 and 43.*]

STEAM LOCOMOTIVES—REPAIRS.

This account includes cost of material used (less salvage) and labor expended in repairing steam locomotives and tenders, and *fixtures thereof (except as otherwise provided for); such as air signal equipment, including hose, arm rests, awnings*, brake fixtures, *cab and steam-gage lamps, cab cushions, clocks, coal boards, fire extinguishers permanently attached to locomotives, gongs, head lamps*, pneumatic sanding equipment, *seat boxes, speed recorders*, steam and other power brakes, *steam-heat appliances, including hose and all other appliances of like nature, storm doors, tool boxes;* also cost of supervision; *pay of locomotive inspectors engaged in inspecting all parts of locomotives and tenders* (except pay of smokestack and ash-pan inspectors, which should be charged to account "Enginehouse Expenses—Yard" or "Enginehouse Expenses—Road"), pay of employees engaged in sponging tender, driving and truck boxes of locomotives undergoing repairs in shops (but pay of employees similarly engaged on locomotives not undergoing repairs in shops should be charged to account "Enginehouse Expenses—Yard" or "Enginehouse Expenses—Road"), and cost of cutting up condemned locomotives and tenders; small hand tools used exclusively in locomotive repairs; special service, such as bringing locomotives to shops or watching them while on the way to shops for repairs, and trying locomotives after having been repaired; traveling expenses of employees whose pay is chargeable to this account; and payments of royalties, or for patent rights on brakes, brake fixtures, and other appliances used on locomotives; also proportion of shop expenses as provided in Note following account "Other Expenses."

The value of old material released during repairs and insurance recovered should be credited to this account.

Note A.—The word "repairs" as here used *includes all repairs on or renewals of parts of locomotives and tenders commonly known as steam-locomotive fixtures or attachments*, and classified as running or roundhouse repairs; *also repairs to or renewals* of the more important or vital parts of locomotives and tenders, the necessity for which is *caused by breakage, failure, or accident while in service;* also the repairs to a steam locomotive or tender damaged through accident or otherwise, necessary to restore it to service: and also renewal of important or vital parts made necessary by reason of age or wear and tear from use.

Note B.—The cost of repairing steam locomotives and tenders of foreign lines waybilled as freight, damaged in transit, should be charged to account "Loss and Damage—Freight," and the cost of repairing steam locomotives of foreign lines having trackage rights over a carrier's line damaged in collision or wreck for which a carrier is liable should be charged to account "Damage to Property."

[*From Page 68.*]

ENGINEHOUSE EXPENSES—YARD.

This account includes *pay of, and cost of supplies furnished* to callers, watchmen, and other *employees* engaged in wiping, cleaning, firing up, *dumping, boiler washing*, cleaning fire boxes, watching, and dispatching locomotives; and of other enginehouse employees, such as *tool checkers*, enginehouse cleaners, *cinder pit cleaners*, clinker dumpers, truck packers, turntable operators, *sand dryers*, inspectors of smokestacks and ash pans, when engaged in caring for locomotives in yard or terminal service; also a proportion of wages paid enginehouse foremen and their clerks.

Some of the more important items chargeable to this account are: *Boiled oil, lampblack, rags, waste, lye, cleaning and polishing compounds, tools for truck packers and hostlers, signal lights on turntabes and transfer tables at enginehouses*, expenses of operation of such tables by power; heating and lighting enginehouses and offices in them; oil for lubricating turntables; *shovels, wheelbarrows, and other tools for cleaning around enginehouses and handling cinders;* rent of cinder cars used at cinder pits; *hose* and water *for cinder pits and for washing out boilers*; cupboards in enginehouses, mechanical blowers and fire lighters for starting locomotive fires.

Note.—When enginehouse expenses are incurred jointly for yard and road locomotives they should be apportioned on basis of number of locomotives of each class handled.

[*From Page 69.*]

OTHER SUPPLIES FOR YARD LOCOMOTIVES.

This account includes the cost of *headlight and signal oil and wicks used in headlights, signal lights, and enginemen's torches; supplies for electric-light dynamos and carbide for acetylene gas for lights on locomotives in yard service;* also the *cost of furniture, tools, and other movable articles and supplies required fully to equip yard locomotives for service.*

[*From Page 70.*]

The following are some of the items chargeable to this account, when furnished for use of yard enginemen:

Ash hoes,	*Hose (not air brake, air signal, or steam),*	*Saws,*
Ash-pan rods,	*Hose reels,*	*Scoops,*
Axes,	*Jacks,*	*Shovels,*
Bars, buggy,	*Jackscrews,*	*Slash bars,*
Bell cords,	*Lamps (signal only),*	*Sledges,*
Boxes (portable),	*Lanterns and parts,*	*Soap,*
Brooms,		*Switch chains,*

Brushes,	*Locks for Portable boxes,*	*Switch ropes,*
Buckets,	*Matches,*	*Switch poles,*
Chimneys, headlights,	*Metallic packing,*	*Thaw-out hose,*
Chisels,	*Oilers,*	*Tool boxes (portable),*
Clinker hooks,	*Oil cans,*	*Torches,*
Crowbars,	*Packing hooks,*	*Torpedoes,*
Files,	*Packing spoons,*	*Water buckets,*
Flags,	*Picks,*	*Water coolers,*
Grate shakers,	*Pinch bars,*	*Wrecking frogs,*
Hammers,	*Plugging bars,*	*Wrenches.*
Handsaws,	*Pokers,*	
Hatchets,		

Note.—For cost of sand, see account "Other Supplies for Road Locomotives."

[*From Pages 71 and 72.*]

ENGINEHOUSE EXPENSES—ROAD.

This account includes *pay of and supplies furnished* to callers, watchmen, and other *employees* engaged in wiping, cleaning, firing up, *dumping, boiler washing*, cleaning fire boxes, watching, and dispatching locomotives; and of other enginehouse employees, such as *tool checkers*, enginehouse cleaners, *cinder pit cleaners*, clinker dumpers, truck packers, turntable operators, *sand dryers*, inspectors of smokestacks and ash pans, when engaged in caring for locomotives in road service; also a proportion of wages paid enginehouse foremen and their clerks.

Some of the more important items chargeable to this account are: *Boiled oil, lampblack, rags, waste, lye, cleaning and polishing compounds, tools for truck packers and hostlers, signal lights on turntables and transfer tables at enginehouses*, expense of operation of such tables by power, heating, and lighting enginehouses and offices in them, oil for lubricating turntables, *shovels, wheelbarrows, and other tools for cleaning around enginehouses and handling cinders;* rent of cinder cars used at cinder pits; *hose* and water *for cinder pits and for washing out boilers;* cupboards in enginehouses, mechanical blowers and fire lighters for starting locomotive fires.

Note A.—When enginehouse expenses are incurred jointly for yard and road locomotives, they should be apportioned on basis of number of locomotives handled.

Note B.—Cost of enginehouse expenses on locomotives engaged in work-train service should be charged as a part of work on which engaged.

[*From Page 73.*]

OTHER SUPPLIES FOR ROAD LOCOMOTIVES.

This account includes the cost of *headlight and signal oil and wicks used in headlights, signal lights, and enginemen's torches; supplies for electric light dynamos and carbide for acetylene gas for lights on locomotives in road service;* also the *cost of furniture, tools and other movable articles and supplies required fully to equip road locomotives for service; fuel for sand dryers and cost of sand and of loading it at sand pits; wheelbarrows, shovels, and sand screens used in handling sand for road locomotives.*

The following are some of the more important items chargeable to this account:

Ash hoes,	*Hose (not air brake, air signal, or steam),*	*Sand,*
Ash-pan rods,	*Hose reels,*	*Saws,*
Axes,	*Jacks,*	*Scoops,*
Bars, buggy,	*Jackscrews,*	*Shovels,*
Bell cords,	*Lamps (signal only),*	*Slash bars,*
Boxes (portable),	*Lanterns and parts,*	*Sledges,*
Brooms,	*Locks for Portable boxes,*	*Soap,*
Brushes,	*Matches,*	*Switch chains,*
Buckets,	*Metallic packing,*	*Switch ropes,*
Chimneys (headlight),	*Oilers,*	*Switch poles,*
Chisels,	*Oil cans,*	*Thaw-out hose,*
Clinker hooks,	*Packing hooks,*	*Tool boxes (portable),*
Crowbars,	*Packing spoons,*	*Torches,*
Files,	*Picks,*	*Torpedoes,*
Flags,	*Pinch bars,*	*Water buckets,*
Grate shakers,	*Plugging bars,*	*Water coolers,*
Hammers,	*Pokers,*	*Wrecking frogs,*
Handsaws,		*Wrenches.*
Hatchets,		

Note A.—Cost of other supplies for locomotives engaged in work-train service should be charged as a part of the work on which engaged.

Note B.—The cost of sand as between yard and road locomotives being undetermined, the entire cost of sand issued to all locomotives should be charged to this account.

The Interstate Commerce Commission prescribed accounts are the basis of our records—legally must be the basis. Those portions of them relating at all to locomotive supplies and equipments, and the handling of these supplies, etc., have been quoted in extenso, verbatim. For the purpose of seeing more clearly the items included in this mass of text, let us rearrange them in list form, and omit all text not strictly relevant to the supplies or their handling expense. There follows such an arrangement.

NEW LOCOMOTIVES—STEAM AND ELECTRIC.

Appurtenances, Furniture and Fixtures.

LOCOMOTIVE REPAIRS—STEAM AND ELECTRIC.

Material (less salvage); labor; fixtures; air signal equipment including hose; arm rests; awnings; cab and steam-gage lamps; cab cushions; clocks; coal boards; fire extinguishers permanently attached; gongs; head lamps; seat boxes; speed recorders; steam heat appliances including hose and appliances of like nature; storm doors; tool boxes; also supervision; locomotive inspectors; repairs on or removals of parts of locomotives and tenders, known as fixtures or attachments, caused by breakage, failure or accident.

ENGINEHOUSE EXPENSES—YARD AND ROAD.

Pay of and supplies furnished to employees; dumping; boiler washing; tool checkers and sand dryers; boiled oil; lampblack; rags; waste; lye; cleaning and polishing compounds; tools for truck packers and hostlers; signal lights on turntables; shovels; wheelbarrows; tools for cleaning around enginehouses and handling cinders; hose for cinder pits and for washing out boilers; cupboards in enginehouse.

OTHER SUPPLIES AND OIL FOR LOCOMOTIVES—YARD AND ROAD.

Headlight and signal oil and wicks; supplies for electric light dynamos carbide for acetylene gas; furniture; tools; movable articles and sup-

plies; fuel for sand dryers; sand and loading it; wheelbarrows; shovels; sand screens.

These are the items which the accounts must show. From what sources do we get the charges? The following will be a fairly complete analysis, although practice varies greatly on different roads:

Requisition for furniture for locomotives undergoing repair.
Requisition for material drawn to repair equipment.
Division Master Mechanic's Payroll, Repair Shop:
Time of inspectors, spent in inspecting locomotive equipment; cost of labor looking after and repairing equipment of engines in shops; time of clerks spent in drawing up special supervision accounts.
Requisition for locomotive supplies, yard.
Requisition for locomotive supplies, road.
Requisition for locomotive headlights and signals, yard.
Requisition for locomotive headlights and signals, road.
Ice drawn by enginemen.
Bills from foreign companies for supplies furnished at joint stations.
Material specially ordered, or specially made in shops, for test or experimental purposes.
Requisition for sand dryers' tools.
Fuel stock for sand dryers: Issued direct and directly charged on requisition, or apportioned on an arbitrary basis and when collected against the account for locomotive supplies, credited on account to which originally charged.
Bills and vouchers from contractors for sand furnished.
Division Superintendent's Payroll: Time of men engaged in loading and unloading sand for locomotive use, and in screening or working on it.
Time of sand dryers drying and unloading sand: (Time of hostlers or others putting sand on engines is not included here.)

APPROXIMATE APPORTIONMENT IN DETAIL OF VARIOUS EXPENSES CONNECTED WITH LOCOMOTIVE SUPPLIES AND EQUIPMENTS.

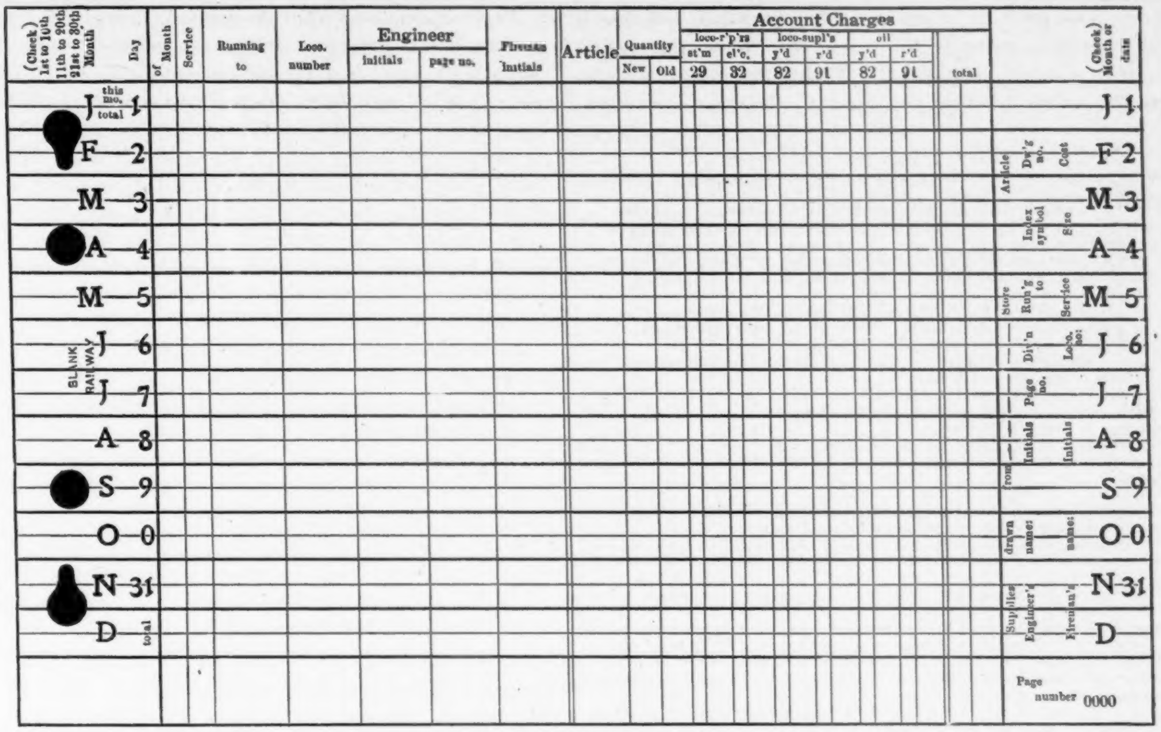
Item No.	Material.	I. C. C. accounts charged to	Approximate net charge under efficient and economical system per: Engine per month. At-tainable min.	Engine per month. Max. al-lowable.	Engine per year. Min.	Engine per year. Max.	1,000 engines one year. Min.	1,000 engines one year. Max.	% of total cost.
100	Appurtenances, furniture and fixtures.	New locomotive equipment, steam and electric loco's.	$20 to $60. value of one complete equipment.		....	....	$20,000	$60,000	(60)
200	Renewals of fixtures, appliances, attachments.	Locomotive repairs. 29 steam loco's. 32 elec. loco's.	$0.15	$0.25	$1.50	$3.00	$1,500	$3,000	5
400	Headlight and signal oil.	Other supplies for locomotives. 82 yard loco's 91 road loco's	.80	2.00	10.00	25.00	10,000	25,000	27
500	Supplies, furniture, tools, movable articles.	Ditto.	.60	1.00	7.00	12,00	7,000	12,000	20
600	Fuel for sand dryers.	Ditto.	.05	.10	.50	1.00	500	1.000	2
700	Sand.	Ditto.	.05	.15	.50	1.50	500	1,500	2
800	Wheelbarrows, shovels and screens.	Ditto.	.05	.10	.50	1.00	500	1,000	2
300	Supplies, tools, cupboards for employes in engine houses	Enginehouse expenses. 78 yard 87 road	.40	1.00	5.00	15.00	5.000	15,000	13
900	Stationery and printing.	50 (M. of E.)	.01	.02	....	....	....	....	....
1000	Stationary and printing.	103 (C. T.)	.01	.03	....	.50	....	500	1
	Total material.................		$2.12	$4.65	$25.00	$59.00	$25,000	$59,000	72

Expense vouchers of supervisors of locomotive supplies and assistants.
Superintendent Motive Power Payroll: Supervisor of locomotive supplies and clerks. Time of draughtsmen on standard drawings.
Requisition for tools, supplies, apparatus and furniture used by enginehouse employees.
Division Master Mechanic's Payroll—Enginehouses: Time of firemen, inspectors, supply men, equippers, tool checkers, hostlers, and clerks spent directly on the inspection of, care of, and repair of, and accounting locomotive supply equipments.

The items of principal cost, and of principal interest to us, are those constituting the actual equipment carried on engines. That this is the case is evident from the following table, subdividing the various accounts (as built up from the several sources just listed) according to the *kind* of expenditure. The subdivision has been shown, also the numerical order of the accounts in the Interstate Commerce Commission classification, and a fair average of best practice proportions of expenses among the several accounts also shown on the basis of monthly and yearly costs per engine (with maximum and minimum limits in which good practice should find itself), on the basis of the total annual charges for these expenses to a road with 1,000 locomotives, and also each item as a per cent. of the total. Of course the latter figure is only a rough approximation.

APPROXIMATE APPORTIONMENT IN DETAIL OF VARIOUS EXPENSES CONNECTED WITH LOCOMOTIVE SUPPLIES AND EQUIPMENTS.

Item No.	Labor.	I. C. C. accounts charged to	Approximate net charge under efficient and economical system per: Engine per month. At-tainable min.	Engine per month. Max. al-lowable.	Engine per year. Min.	Engine per year. Max.	1,000 engines one year. Min.	1,000 engines one year. Max.	% of total cost.
202	Labor.	29 32	.05	.10	.50	1.00	$500	1,000	2
220	Supervision.	29 32	.05	.15	.50	2.00	500	2,000	2
222	Loco. inspectors.	29 32	.05	.10	.50	1.00	500	1,000	2
1050	Superintendence and expenses.	66 (C. T.)	.10	.20	1.00	2.50	1,000	2,500	3
305	Pay of employes and tool checkers.	78 87	.40	.60	5.00	7.00	5,000	7,000	12
308	Sand dryers.	78 87	.08	.20	1.00	2.50	1,000	2.500	2
303	Truck packers and hostlers.	78 87	.15	.25	1.50	2.50	1,500	2,500	5
	Total labor....................		.88	1.60	10.00	18.50	10,000	18,500	28
	Grand total............................		$3.00	6.25	35.00	77.50	35,000	77,500	100
	Average......		3.50	5.00	40.00	60.00	40,000	60,000	......
	Other sup'lies for locomotives excluding oil.	82 91	.60	1.00	7.00	12.00	7,000	12,000	20
	Headlight and signal oil.	Ditto.	.80	2.00	10.00	25.00	10,000	25,000	27
	Total above.	Ditto.	1.40	3.00	17.00	37.00	17,000	37,000	47
	Total of account (items of 400, 500, 600, 700, 800)	Ditto.	1.55	3,35	18.50	40.50	18,500	40,500	53
	Locomotive supplies only including labor and supervision directly connected therewith (items 200, 500, 900, 1000, 202, 220, 222, 1050, 305).		1.42	2.45	16.00	29.00	16,000	29,000	47
	And excluding oil, sand and engine-house expenses not directly concerned with supplies carried on locomotives (i. e., excluding items 300, 400, 600, 700, 800, 308, 303).		3.00	6.25	35.00	77.50	35,000	77.500	53



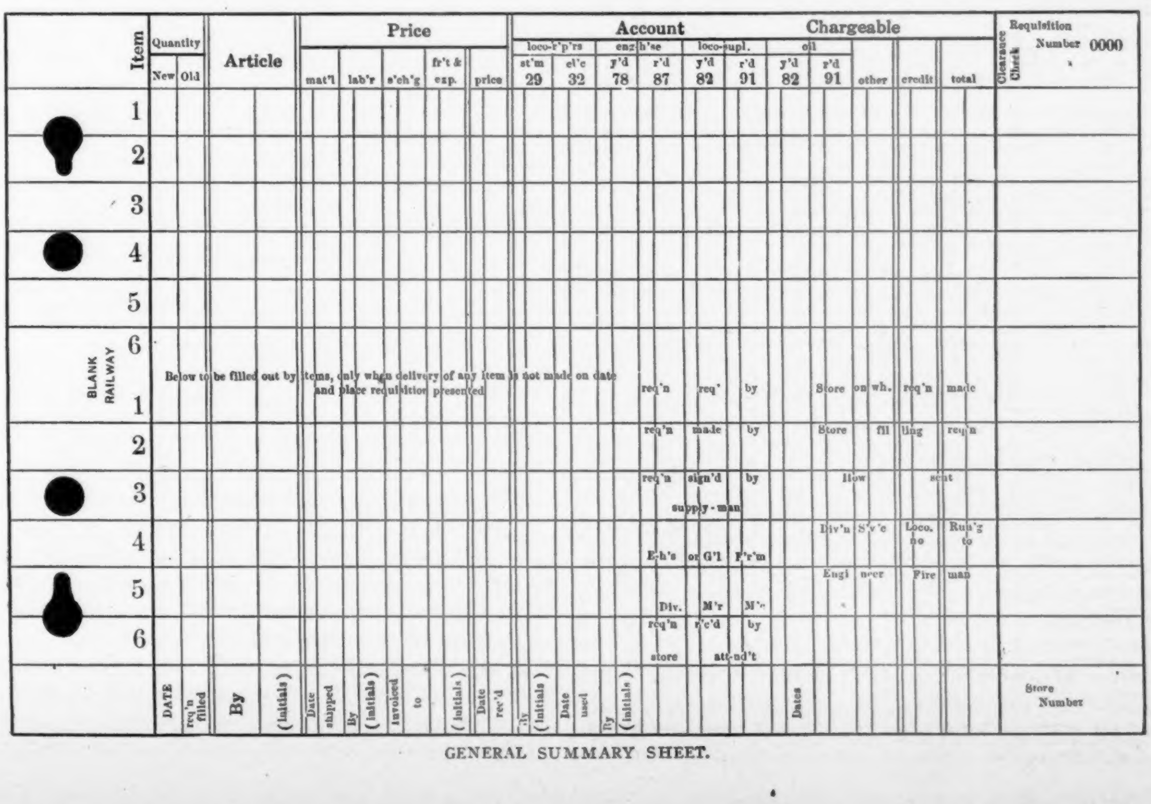
ORIGINAL REQUISITION BLANK.

As we are most interested in the history of the engine equipment and supplies proper, it will be well to give detail forms for use in handling this phase of the matter. Two basic forms are submitted, one an original requisition blank, and the other a general summary sheet. The requisition here shown is not meant altogether to be adopted as it stands in toto for practical use, but it is meant to give almost all the data required for complete supervision purposes. Actually, no doubt, several items of information shown might be omitted without detracting from the efficiency of the general accounting scheme.

The other form, that showing summaries and recapitulations, had its origin in the brain of one of our best railroad general storekeepers. He is not responsible for the present form of the record, but the general principle of a daily distribution sheet, giving a line to each day, and columns for the several accounts and subdivisions of accounts, is his, and it has worked out most excellently in looking after over $30,000,000 worth of material issues per year. The adaptation of the loose leaf principle to this record is also due to his suggestion.

The forms are 5 x 8 in. in size; are printed in light brown ink so as to leave the written record more conspicuous than the printing; are printed on cheap manila paper and furnished in pads of 150 gummed together on the binding edge; are punched for loose leaf use; are ruled (either color rulings or printed rulings may be used; if color is used the shade of all lines is light blue except those separating dollars and cents which should be in red) in multiples of 1/6th inch (horizontal rulings) and 1/10th inch (vertical), which accords with standard typewriter spacing.

Complete instructions (a suggestion for which is reproduced herewith) are printed on the back of each form, both to insure accuracy in making out the reports, and to prevent the use of the form for scratch pad purposes. The clearance, for old equipment returned, or not returned, will be illustrated in a subse-



GENERAL SUMMARY SHEET.

quent issue. The printing looks somewhat crowded, but this is no serious drawback, owing to the use of the brown ink, so that one may write a legible record over the printed matter without destroying the value either of the form of the record information.

INSTRUCTIONS FOR MAKING OUT REQUISITIONS.

No item of supplies, tools, equipment, fixtures, appliances, furniture, appurtenances, attachments, movable articles and the like, for use on locomotives, may be issued to any engine, engineman, supplyman, equipper, inspector, foreman, mechanic, tool checker, or other person, and charged to a locomotive, or to one of the accounts designated on the opposite side of this form, unless such item is properly requisitioned on this form in triplicate, and signed by the supplyman or person authorized in his place to sign requisition for such material.

Requisition blanks will be furnished periodically as they are used up by those persons authorized to issue them. Take up all correspondence as to requisition with supervisor of locomotive supplies.

Nor will any requisition be honored unless it bears the information required in columns or spaces as follows:

Quantity (indicating what article is new or old).
Article (with correct symbol or unequivocal name).
Correct charge to correct account.
Initials of supplyman or issuer of requisition.
Store on which requisition is made.
Engine number.
Running to.
Engineer's initials (according to authorized list of initials).
Firemen's initials (according to authorized list of initials).

If the article requires a clearance for the old one before a new one is issued, requisition must be accompanied by clearance properly filled out in triplicate.

For instructions as to filling out clearance see back of clearance form (Form 000 Standard).

If clearance is turned in, check in "Clearance Check" column with letter C. If no clearance is turned in, check with letter N. If old article is returned, check with letter O. If no old article is returned, check with X.

Other information should be filled in as far as known and as circumstances require.

Originals of requisitions will be retained by storekeeper honoring same as his authority for the issue of material.

First duplicate will be forwarded promptly on date of issue by storekeeper to office of supervisor of locomotive supplies.

Second duplicate will be retained by supplyman or equivalent person for his permanent file, in the binder provided for the purpose, where it may be referred to at any time. File requisitions numerically.

No requisition blanks shall be destroyed, or used for other purpose; blanks spoiled in any way before use are to be sent with other requisitions to office of supervisor of locomotive supplies.

INSTRUCTIONS FOR FILLING OUT SUPPLY ACCOUNT FORM.

This form is designed to be used for a number of different purposes, so as to reflect to the supervisor of locomotive supplies, various aspects of the detailed information shown on the supply requisition form.

This form will summarize and consolidate the information shown on the requisitions by engines, for purposes of account and distribution; by engineers, for the purpose of fixing responsibility; by firemen for a similar purpose with reference to tools and supplies used by and drawn for them; and by articles, so as to indicate those classes of articles which are occasioning the bulk of the expense, with a view to remedying defects in them in case high expense is caused by defects.

The form is arranged for drawing off the information from the requisitions article by article as drawn, or for issues to engines or enginemen, or by articles for each day, or for each month, or for each year. It will be noted that the lines permit of an entry being made for 10 days, thus requiring three sheets for one month's record; also one line is provided for each month, and provision is made so that the total of given number of months (those since the beginning of the last fiscal or calendar year, for instance, the preceding 11 months added to the month in question, thus giving a yearly total for the 12 months, ending each month; or what is more convenient and practically as good, the preceding 9 months taken together with the current month, making 10 months in all, and thus making apparent at a glance what the average issues per month for a long recent period are).

The plan of having 10 days on a sheet permits of closer touch being kept with these costs than is the case with records that run for a whole month before they are closed, and abuses may be corrected at their inception.

Not only does this form provide individual records variously arranged, and for short and long periods of time, but it may be conveniently used for summarizing or recapitulating the various individual records of engines, enginemen, and articles.

Furthermore, individual items, daily and monthly records of each class, may be also recapitulated for each station where stores are issued, for each operative division, and for groups of divisions.

Particular instructions follow relative to the manner of using this information for each class of record.

RECORD BY ENGINES.

The articles as drawn on requisition will be entered up in detail for all the articles on the requisition. The day of the month will be written in in the first left-hand marginal column provided for that purpose. Entries will be made in all the succeeding columns except that provided for the engine number (which is entered for this sheet in the space provided on the righ-hand margin), engineer's page number, and total account charges.

Referring now to the right-hand margin the following entries only will be made: Supplies drawn from.................. store, division, engine number, "running to" and "service" if permanent assignment.

These individual entries can now be summarized according to any of the desired arrangements without having again to refer to copies of the original requisition form. A daily distribution of the charges on each account, to each engine may be had, omitting reference to specific articles, enginemen or trips. Similarly a monthly distribution may be had.

The engines for a given day, or for all the days of a month, or as a total for a month, may be conveniently summarized on this sheet, showing the total charges to each, for the period desired, on each account and the total for all accounts. In the case of such a summary, all entries would be ignored except the following:

In columns.
Engine number.
Account charges.
In right margin.
Supplies drawn from................ store.
Division.

Without further going into detail in respect to the entries for individuals, and groups, of enginemen, and of articles, it will be readily seen that almost any desired arrangement of entry can be made with this form in order to reflect the actual information desired for supervision purposes.

As an example of what the individual engine record will show, an instance is given of charges to six engines for supplies and equipments furnished during one single month. These engines were received new from the locomotive works, and had to travel over about 1,000 miles of foreign rail lines and about 400 miles of home lines before they reached the central shop where they were to be set up and made ready for service. It was found, by the time they were ready to "break in" that most of the equipment which had been ordered with them from the builders, and which had been placed on them at the locomotive works, was altogether missing, and nearly complete new equipment had to be provided.

The engines were then sent to the division on which they were to operate, another 800 miles away. After undergoing another "setting up," this was the cost of the equipment that was supplied to each engine:

Engine.	Charges.
6	$67.28
7	81.22
8	93.59
9	101.65
10	87.32
5	97.85
Total for six new engines	$528.35
Average	88.07

The average cost is in excess of the total cost for a complete equipment, as per standard equipment form; this form, however, included many items that were never applied in practice to the engine. The total value of equipment according to the form was about $84.00; the value of the supplies, etc., actually put on when the engines were fully equipped for road service was in the neighborhood of $70.00. It will be seen that one of the engines in this list exceeded the cost of a total equipment by nearly 40 per cent.

With these figures at hand, the attention of all concerned was so forcibly drawn to the shockingly wasteful cost that when the next lot of engines came over the same route, the charges were reasonable. This is an illustration of what proper accounting will reveal to him who wishes to supervise efficiently.

Not more than $2.00 worth of supplies need to be drawn on an average, per month, per engine. In one month, the issues classified according to value, were as follows on three divisions of a certain road:

NUMBER OF ENGINES DRAWING EQUIPMENT.

Division	under $1.00	under $2.00	under $3.00	under $4 00	Over $4.00	Highest Amount Drawn for one Engine
A	24	23	12	10	37	$75.46
B	34	17	14	8	24	20.48
C	30	16	12	7	20	19.62

It is evident that over one-half the engines do get along drawing an average of less than $2.00 per month.

If we take a period of several months for a division, this is still more evident.

PERIOD COVERED—SEVEN MONTHS.

	About $1.00	Under $2.00	Under $4.00	Under $5.00	Over $5.00
Engines	$ .09	$ .14	$ .20	$ .06	$ .07
Total Amount	69.09	163.18	417.95	181.60	427 01
Average per engine	7.12	11.66	20.89	30.77	61.11
Average per engine per month	1.02	1.67	2.99	4.32	8.73

Highest for one engine—period seven months.. $94.17
Average per month for that engine............ $13.45

To only 12 per cent. of the engines 35 per cent. of the issues go, or to one-quarter of the engines, half. Yet over half the engines, through this whole period, get along with an average of less than $2.00 issues per month.

It would naturally seem as if the lowest records made by engineers for small tools and supplies will be most rapidly acquired on small engines in branch service.

But after having gone very carefully into the matter, and using

as a basis of comparison the ratio of engineers' wages to cost of supplies issued, the mileage or the service of the engine being proportional to these wages, it becomes evident that the larger and main line engines actually seem to cost less. Taking one month on one particular division we find that for every dollar in wages paid to the engineer, the amount of supplies drawn, averaged over all engines in each class of service, is as follows:

Large main line engines	$0.0200
Small main line engines	.0462
Small branch line engines	.0750
Engines in switch service	.0201

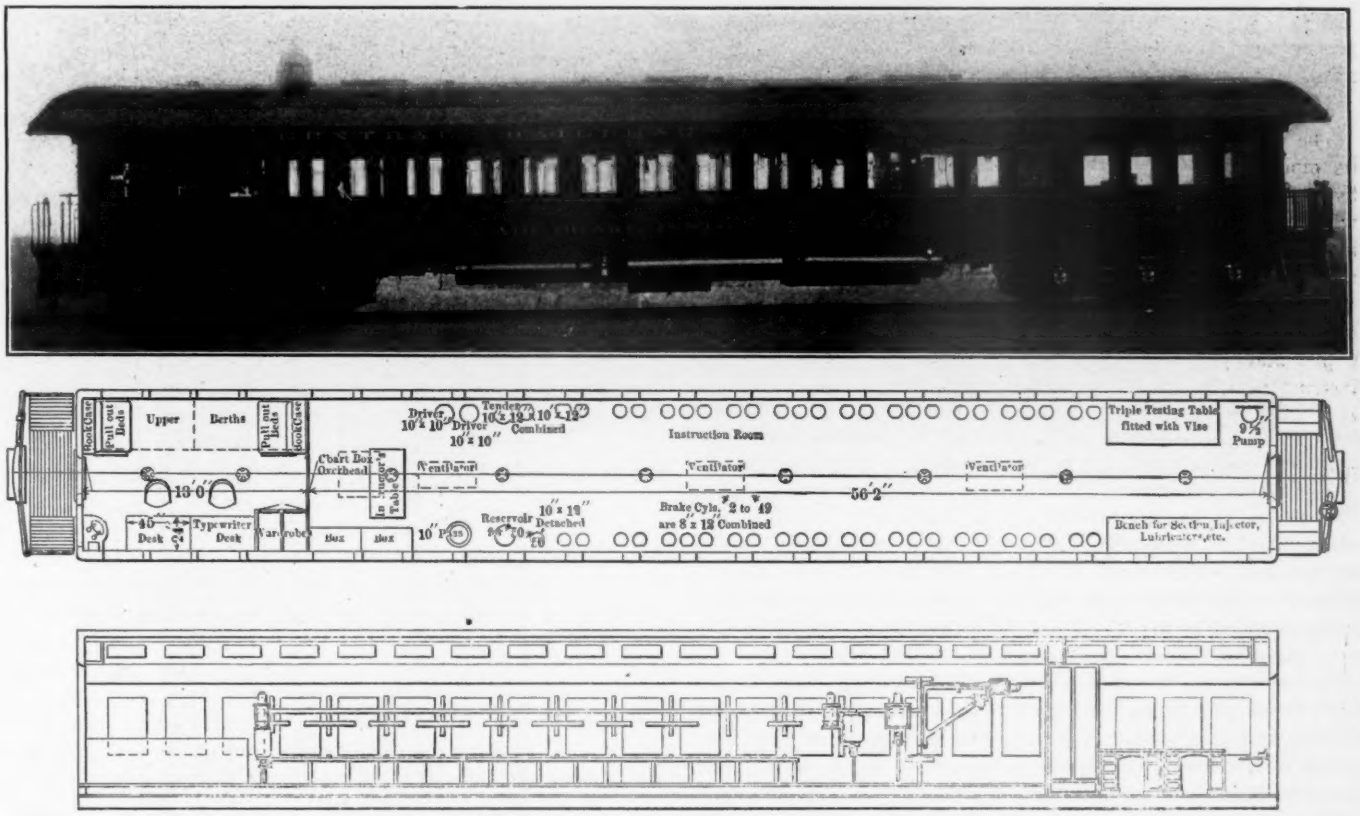
The "Primary Transportation Accounts" known as "Other Supplies for Locomotives" in yard and road service, are insignificant in gross amounts, compared with most other subdivisions of operating expense; they actually run from 1/4 of one per cent. to less than one per cent. of the total conducting transportation expense, and it may seem that undue prominence is being given in this article to the petty details of a trifling and unimportant matter. Yet it must be remembered that it is often a serious matter for a locomotive to run improperly equipped, that if first attention is given to efficiency in this matter, economies are sure to result, and that such economies will amount to thousands and in some cases even hundreds of thousands of dollars per year; the improvement and the savings of revenue for net earnings are both worth the effort involved in securing them; and it should be noted that the analytical method here outlined, upon which the constructive work of intelligible and correct accounting and economical efficient supervision is built, is applicable to many large fields of railway operation. Readers should keep this *method* in view when perusing this article, as a principle of much greater value than even the profitable proposition of handling locomotive supplies.

RECORD OF LOCOMOTIVE EQUIPMENT COSTS OF A ROAD OWNING ABOUT 1,100 LOCOMOTIVES, SHOWING REDUCTIONS EFFECTED. THIS ACCOUNT WAS TOTALING ABOUT $80,000 PER YEAR, AND WAS ON THE INCREASE, WHEN TAKEN HOLD OF.

	Issues to Locomotives.		Pay of tool checkers second year.
	First year.	Second year.	
January	....	$1183	$1056
February	....	1509	911
March	....	1612	918
April	....	1581	887
May	$4916	1504	978
June	4996	1673	845
July	4132	1110	....
August	1519	....	....
September	1395	....	....
October	1469	....	....
November	1392	....	....
December	1182	....	....

NOTE OF ERRATUM.

On page 8 of the preceding instalment of this article appeared two diagrams giving the cost of locomotive supplies in American railway practice in tenths of a cent "per revenue ton mile;" the legends (and also line 2, from the bottom, second column, of the same page) should have read, in tenths of a cent "per 100 revenue ton miles."



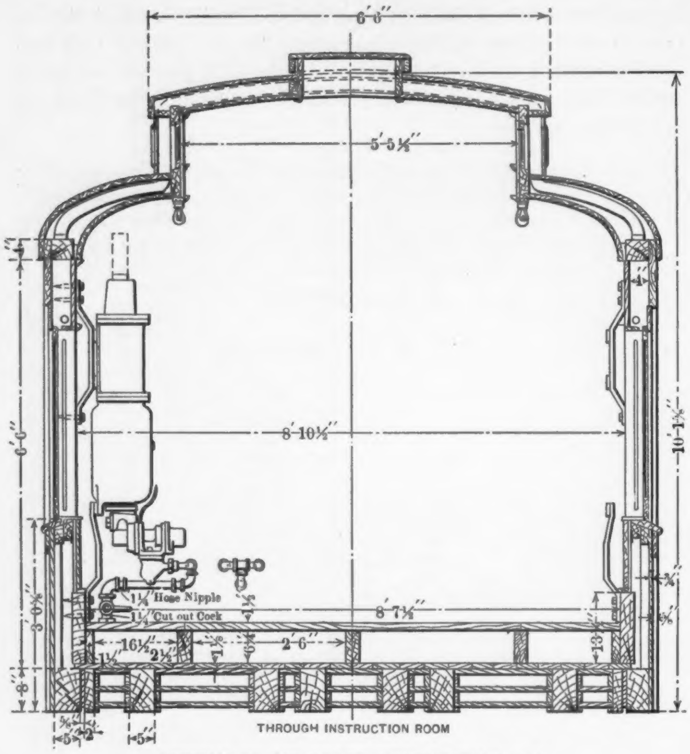
AIR BRAKE INSTRUCTION CAR—CENTRAL RAILROAD OF NEW JERSEY.

AIR BRAKE INSTRUCTION CAR.

CENTRAL RAILROAD OF NEW JERSEY.

The Central Railroad of New Jersey has just completed at its Elizabethport shops a very completely equipped and excellently arranged air brake instruction car. This car was designed in the mechanical engineer's office and consists of a wooden passenger car body, 70 ft. over end sills, in which is included complete air brake equipment for a 50-car freight train, a 5-car passenger train with locomotive and tender, as well as other separate and special brake, lubricator and injector parts.

The car is divided into two compartments, one 13 ft. long, equipped as an office and containing two desks, book-cases, berths, clothescloset, wash-basin, etc., and the instruction room, which is 52 ft. long. The 50-freight-brake cylinders are hung from iron racks along each side of the car, in the instruction room, and each is provided with a double bracket with three-way valve for the attachment of the "K" and "H" triple valve, either of which may be cut into service or both cut out entirely. The triples set in a horizontal position the same as in regular service. Gages with large dials are connected at different points and can be read from the end of the compartment. A full length of standard sized pipe accompanies each brake cylinder and is arranged in sections resting on the regular car flooring. A false flooring, secured to sub sills, covers this piping. Any portion of this false floor can readily be removed for inspection and by the use of cut-out cocks it is possible to cut the brake cylinders into groups and give the



SECTION OF AIR BRAKE INSTRUCTION CAR.

proper number of brakes for a 5, 10, 20, 30, 40, 45 and 50-car train.

The illustration shows the arrangement of the apparatus and its piping. The 5-car passenger train is obtained by equipping five of the freight cylinders with a high speed reducing valve which can be cut in if desired. The 10-in. passenger brake cylinder, which has a slack adjuster and a P1 triple in tandem, is mounted upon a crane and can be swung out in front of the instructor's table. On the opposite side of the car is another crane supporting two 10-in. brake cylinders with K and L triples and sectional triples arranged in tandem. The air signal instruction apparatus consists of a 12-car train equipment, and is located under the lower deck on each side.

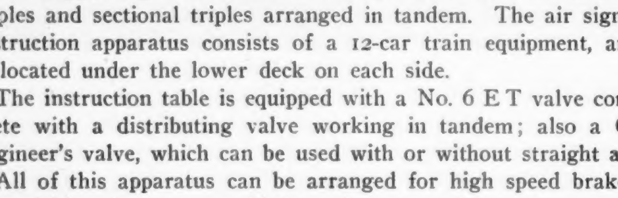
The instruction table is equipped with a No. 6 E T valve complete with a distributing valve working in tandem; also a G6 engineer's valve, which can be used with or without straight air.

All of this apparatus can be arranged for high speed brakes. The 9½-in. air pump provided can be operated by steam or air, either direct or compound, thus being able to furnish any desired air pressure. This pump is operated by steam or air connections from pipe lines at the various shops or stations, no boiler being provided in the car. The auxiliaries for the driver, tender and passenger cylinders are located under the car.

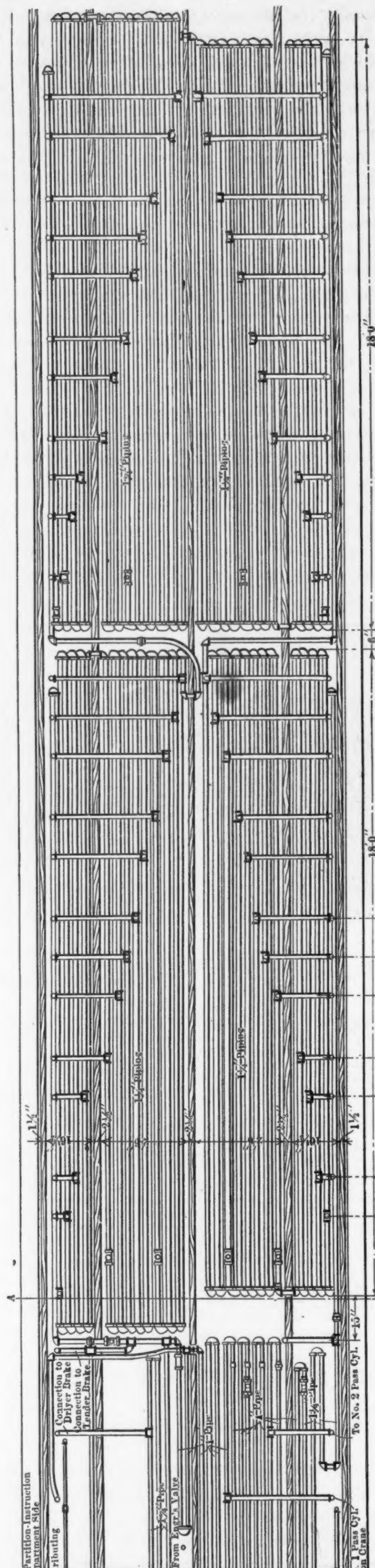
In addition to the usual method of ventilation three hatchways fitted with hinged covers have been arranged in the center of the roof. No accommodations for cooking have been provided, since the car will always be located at points where hotel accommodation can be secured.

The underframe consists of eight 5 x 8 in. wooden sills, the side sills being reinforced by ⅝ x 7 in. iron plates. Four truss rods are included and the window posts are made solid, so as to provide secure support for the brake cylinder brackets. The lighting is by Pintsch gas and the car is also wired for electric lights, the current being obtained from the circuits at the various shops.

This car and the arrangement of its equipment was designed by Mr. B. P. Flory, mechanical engineer, and Mr. G. W. Rink,



SECTION SHOWING PIPING.



ARRANGEMENT OF PIPES ON FLOOR OF INSTRUCTION CAR—CENTRAL RAILROAD OF NEW JERSEY.

INTERIOR OF AIR BRAKE INSTRUCTION CAR—C. R. R. OF N. J.

chief draftsman, under the supervision of Mr. William McIntosh, superintendent of motive power. It has the following general dimensions:

Length over end sills	70 ft.
Width over side sills	9 ft. 8 in.
Length of instruction room	52 ft. 2 in.
Length of office	13 ft.
Truck, type	Six wheel, 5 x 9 in. journals
Weight of car, complete	150,000 lbs.

LUBRICATION OF AIR COMPRESSORS AND PNEUMATIC TOOLS.

The lubrication of compressors and pneumatic tools is a feature deserving careful attention. A too frequent mistake is made by using in air cylinders of compressors oil intended for steam cylinders. Such oil is of low flash point, whereas, the power lubrication of air cylinders demands a light oil of high flash point and of very best quality. Oil of poor grade and low flash point becomes vaporized in air cylinders and is discharged with the air without effecting lubrication.

Oil should be fed to air cylinders slowly and sparingly, as too much oil will clog the air valves, causing them to stick and give trouble. Air valves should be examined and cleaned at intervals by washing in kerosene or naphtha. When this is done, the valves should be removed from the compressor. Engineers have been known to introduce kerosene through the air-inlet pipe, an effective method of cleansing dirty valves, but sometimes equally effective in producing an explosion, since the oil forms a fine spray or mist which, when compressed with the air, produces a condition similar to that in the cylinder of an oil engine.

The feeding of soap-suds into the air cylinder through the lubricator is excellent for keeping valves clean, but when this is done oil should be fed through afterward to prevent rust.

The lubrication of pneumatic tools is of equal importance. One cannot do better than obtain and use one of the several brands of oil furnished by pneumatic tool makers who have made a special study of the requirements. Such oil is necessarily light, and under no circumstances should a heavy oil be used, as the cooling effect of the expanding air would cause it to clog the tool parts and prevent the free movement of the parts.

Pneumatic hammers should be carefully cleaned after using, and kept submerged in a tank of oil when not in service. An excellent device for effectively lubricating pneumatic tools is an automatic oiler inserted in the supply hose about 20 inches from the tool with oil-proof hose between oiler and tool, which, operating on the principle of an atomizer, enables the flow of the lubricant to be regulated to a nicety.—*Mr. W. P. Pressinger before the Central Railway Club.*

ELECTRO-PNEUMATIC BRAKE FOR RAILWAY TRAINS.—The January issue of the Bulletin of the International Railway Congress includes a description of a new electric brake, which has recently been devised by Messrs. Siemens & Halske, and which is arranged to properly proportion the brake pressure to the coefficient of friction, so that the maximum amount of braking power is obtained at all times. The apparatus is all supplementary to the regular air brake equipment of the Westinghouse type and includes an extra brake cylinder and reservoir on each car. The pressure in the former is regulated by an electric gear operated by a mercury inertia regulator. A three-wire circuit is carried throughout the length of the train and the proper electrical apparatus and connections are made at each car and on the locomotive, so that the supplementary electrical action will be entirely automatic for ordinary stops and give a pressure in addition to that of the regular application, which will be relieved as the speed is decreased. A connection is made to the engineer's valve, so that in case of an emergency stop both the air and electric appliances are thrown into full use.

INTERESTING LOCOMOTIVE CONSTRUCTION.—The pistons in the cylinders are connected to the four coupled driving wheels by a mechanism constructed according to most recent practice; in short, from piston rod to cross head through connecting rod to driver.—*Exchange.*

SUPERHEATED STEAM FOR LOCOMOTIVES.*

By Robert Garbe.†

Among the improvements in locomotive construction none has excited greater interest in professional circles than the application of highly superheated steam in current locomotive practice. Ten years ago few, even among the most far-seeing of practical locomotive engineers, were willing to admit of the possibility of permanently and regularly producing steam at temperatures of 550 to 650 degs. F. within the restricted capacity of an ordinary locomotive boiler and of its safe and economical application to the ordinary running of an engine; while at the present time it has found successful application in more than 2,000 locomotives, if we include those in construction with those actually running. Dry or moderately superheated steam has been tried on different occasions, but without realizing any notable economic advantage in practice, and it was not until Mr. William Schmidt, of Cassel, had developed practical methods of applying high superheat that its use became possible in stationary engines about 1880, while fifteen years later the first steps were taken in extending it to locomotives.

From the beginning of the trials which were made at this time on the Prussian State Railways it became apparent that an effective locomotive superheater could only be realized by making it a closely connected integral part of the boiler itself, receiving its heat from the live flames of the fire grate and not from waste gases or an independently fired apparatus.

Properties of Hot Steam.—According to Schmidt the term "hot steam" is to be understood as meaning steam that has been raised to 180 degs. F. above its proper saturation temperature. An appreciation of the method of producing and using superheated steam will be much facilitated by a preliminary consideration of the more important properties in which it differs from saturated steam.

The specific volume of saturated steam diminishes with increase of temperature, while on the other hand the volume of superheated steam increases nearly directly in proportion to the rise of temperature. The specific volume for superheat of 200 degs. is increased approximately 25 per cent., and thus for the same cut-off in the cylinder the weight of steam required is about 25 per cent. less with 200 degs. superheat than with saturated steam with the same pressure.

This augmentation of volume is, however, a less important advantage than that realized by the suppression of all cylinder condensation when the superheat is sufficiently high. Under ordinary average working conditions with saturated steam about 35 per cent. of the total quantity admitted immediately precipitates without doing any mechanical work and passes through the engine as suspended water in the steam. Highly superheated steam, on the contrary, does not lose any of its capacity as a working agent. This condition is augmented by the low thermal conductivity of the superheated steam; while saturated steam is a good conductor of heat, highly superheated steam is a very bad conductor. This property, which is of great value in reducing the loss by cooling in the cylinders, is, on the other hand, an obstacle to the free transmission of the heat to the steam in the superheater and calls for special consideration in its design.

In order to realize the great economical advantage of hot steam, increased volume and avoidance of cylinder condensation, a certain heat expenditure must be debited to the saving due to the above items.

The heat necessary to rise one pound of saturated steam from its proper temperature T to a higher temperature t degrees F is:

$$W_1 = C\ (t - T)\ \text{B.T.U.}$$

C being the specific heat of the superheated steam under constant pressure.

Putting W equal to the quantity of heat contained per pound of steam saturated at this particular pressure, then $W_2 = W + W_1 = W + C\ (t - T)$ expresses the heat value of the superheated steam; that is, the total heat contained in one pound of steam superheated to the temperature t.

According to the latest researches the specific heat of steam is not constant, but varies with the temperature and pressure. The mean values for the temperatures and pressures current in locomotive practice are shown in the following table:

Pressure	128	156	185	213
Saturation temperature	354° F.	369° F.	381° F.	392° F.
Specific heat at temperature 392° F.	.597	.635	.677	......
" " " " 482° F.	.552	.570	.588	.609
" " " " 572° F.	.530	.541	.550	.561
" " " " 662° F.	.522	.529	.536	.543

The heat requirements of the superheater are not limited to the amount W_1 necessary for supplying the actual superheat, but must be supplemented by the quantity for evaporating particles of water mechanically carried into the superheater. Assuming a degree of humidity in the boiler steam of 7 per cent., which for ordinary locomotive working conditions is certainly not excessive, the heat demand for the production of one pound of steam at 170 lbs. pressure and 572 degs. F., temperature from the heating surface of the boiler and superheater, will be as follows:

	B. T. U.
From the boiler surface:—	
.93 lb. dry saturated steam = .93 × 1,194.3 =	1,111
.07 lb. water at saturation temp. = .07 × 340.5 =	24
	1,135
From the superheater:—	
Evaporation of .07 lb. water at 368.3° F = .07 × 853.8 =	60
Superheating 1 lb. dry steam by 204° = .541 × 204 =	110
Total heat required for 1 lb. of hot steam =	1,305

of which 170 or 13 per cent is required from the superheater.

Assuming that 40 per cent. of the total heat is developed in the fire-box and 60 per cent in the tubes, the superheating surface would therefore be 13 per cent. of 60 or 22 per cent. of the total tube surface, and when it is further considered that the best part of this surface nearest to the back tube sheet is unavailable it is readily understood that in order to obtain a sufficient superheat, from 25 to 30 per cent. of the total tube surface of the boiler must be appropriated to that use.

It by no means follows that the superheating surface is directly proportional to the degree of superheat, since to require half of the heat, or to say 473 degs. F., considerably more work is called for than will be furnished by a superheater of only half the heating surface.

Generation of Superheated Steam.—The valuable property of poor thermal conductivity, characteristic of highly superheated steam, is a source of great difficulty in its production. Steam with only a moderate superheat is generally mixed with particles of water or damp steam, the better conductivity of which will rapidly contaminate the whole mixture. In order to supply the heat to all parts of the steam it is required that it shall be divided into numerous thin streams, which by combination with multiple reversals of direction will insure the thorough mixture of the moist and superheated particles. It is very necessary that a high temperature difference shall prevail. That is, the application of highly heated gases is essential.

According to the author's experience an average temperature of 570 degs. F. in the steam chest must be obtained in order to insure the homogeneity of the superheated steam or its freedom from intermixed damp or saturated portions. Repeated trials have shown that the coal and water consumption are decidedly increased when the temperature falls below that level to any extent.

Having regard to the small available space in a locomotive boiler, successful superheating can only be realized by superheaters complying with the following conditions: 1. Application of a sufficiently high temperature in the heating gases. 2. The greatest possible sub-division of the superheater surface. 3. Mixing the steam currents on their way through the tubes and lengthening the passages, so that they are compelled after passing one set of tubes to return by another. 4. Guiding and regulating the draft of the heating gases.

Hauling Capacity Increased.—In addition to a saving in fuel and water a further and more important advantage of superheated steam working is to be found in the notable increased

* Abstract of a series of articles published in the *Engineer* (London) on October 25, November 1, 8, 15, 22, 29 and December 6, 1907.
† Privy Counselor, Prussian State Railways.

hauling capacity of the engine. In comparative trials of two locomotives the superheated engine often showed a saving of about 25 per cent. of coal, each doing the same amount of work. This locomotive could, however, be harder driven, doing about 40 per cent. more work than the other engine and would still give a coal consumption of 10 per cent. less. The superheat, therefore, is to be regarded not merely in the light of saving 25 to 30 per cent. of the coal but as a certain security against the wasteful and objectionable practice of using two engines in front of one train.

Forms of Superheaters.—The method of leading the currents, both of furnace gases and of steam, is of primary importance in determining the efficiency of superheaters. Care must be taken to protect the tubes from the cutting action of the flame and the counter current principle of bringing the coolest steam in contact with the hottest portion of the flues is essential. The question whether the tubes should be arranged transversely or parallel to the current of hot gases cannot be considered being finally settled. The experience with the stationary boilers, however, would indicate that the latter is more favorable to regularity in heating.

The superheater system must include the largest possible number of thick small bore tubes to allow of frequent intermixture of the currents, taking care, however, that steam that has already been superheated should not be brought into contact with that in a damp or saturated condition.

The velocity of the steam in the superheater must be tolerably high in order to prevent overheating the tubes. The upper limit of such velocity is determined by the permissible fall in pressure and is considerably higher than with saturated steam on account of the increased fluidity due to the complete gasification.

Eliminating Condensation.—The conditions holding for working, with saturated steam, which compel the condensation of considerable of the entering steam, which is later evaporated and passes through the cylinder without doing any work and may even, if the piston speed is sufficiently high, remain as water in the cylinder, are advantageously modified when a sufficient degree of superheating is adopted. The heat exchanges during admission, with superheated steam, take place at the cost of the surplus above the saturation temperature, and while the steam is somewhat cooled, it is not sufficient to cause condensation. The loss of working power, due to the contracted volume caused by such cooling, is unimportant. During the exhaust the heat demand on the cylinder walls is comparatively small, especially when a slight superheat still remains, partly because such steam is a poor conductor of heat, and particularly because such heat is directly applied to raising the steam temperature and not for evaporating water. The use of hot steam, therefore, is attained with a much smaller heat interchange and the mean temperature of the cylinder walls is kept at a higher point.

It must, however, be borne in mind that it is only by a very high initial superheating of the steam that cylinder condensation can be prevented during the entire working stroke, and this has been objected to on the ground that with such excessive heating the superheat is not entirely expended and the exhaust passes out at an unnecessarily high temperature. Upon these grounds it has been proposed to limit the superheat so that at the end of the stroke the exhaust will be in a saturated state. The constantly varying demands upon both the boiler and engine of a locomotive necessitate a considerable margin in the power of the superheater above that calculated for normal use and it would hardly be satisfactory to design a superheater to give this condition. Experiments made by Prof. Seeman on a stationary engine show that the heat consumption per indicated horse power fell continuously with each increment of heat of the live steam, notwithstanding the higher temperature of the exhaust, and although similar experiments have not been carried out with locomotives, the numerous trials made by the author have shown that the greatest economy is invariably obtained with the highest steam temperature, notwithstanding the increased temperature of the exhaust steam consequent upon its use.

In order to utilize the increased working power of the boiler, obtained by the addition of the superheater, most completely and economically it is not sufficient to merely increase the length of the admission in the cylinder above that calculated for saturated steam, as the losses due to insufficient expansion and increased back pressure will go far to counterbalance the saving. It is only by an appropriate enlargement in cylinder diameter that the tractive effort, while maintaining an economic figure of admission, can be augmented sufficiently to completely utilize the increased working capacity of the boiler. To realize this the cylinder diameter must be such that the maximum tractive effort is obtained with about 45 per cent. admission and the highest sustained working with 30 per cent. For minimum admission 20 per cent. is the lowest permissible, below that point the working must be regulated by throttling.

The conditions with saturated steam are entirely different. In order to reduce condensation losses the cylinder dimensions must be kept as low as possible, which necessitates a wasteful rate of admission when extra power is required, and it is upon this difference that the superiority of superheated steam depends. Its recognition, as a result of the continuous development of the application of superheating in locomotive construction on the Prussian State Railways, has led to a progressive enlargement of the cylinders. The so-called "characteristic C" of the Prussian hot steam 2-cylinder locomotives is as follows:

$$C = \frac{d^2 l}{D R}$$

where

d = diameter of cylinder in inches
l = length of stroke in inches.
D = diameter of driving wheels.
R = load on driving axle in tons.

This figure lies between 3.9 and 4.7, or considerably higher than is customary, or possibly with saturated steam locomotives. The boiler pressure is 170 lbs. per sq. in.

It may be appropriate to mention, in regard to the difficulties anticipated by many railway experts, as likely to arise from the working parts when continuously running under highly superheated steam, that such difficulties have not, in the large number of locomotives now in use, given rise to any practical inconvenience. Minor difficulties have been completely overcome, and as far back as six years ago forms of pistons, piston valves, and stuffing boxes were settled, which have since proven to be perfectly durable under the highest steam pressures. Lubrication troubles have been eliminated by the use of oils of a sufficiently high flash point combined with a simple method of oiling under pressure.

Economy.—The saving in coal due to the suppression of cylinder condensation with a simple superheated engine approaches about 25 per cent. when compared with that of the saturated steam locomotive of the same weight and to 15 or 20 per cent. when compared with a two or four cylinder compound. For practical locomotive purposes coal consumption alone can be relied upon for comparison under present conditions. Rules have been given at various times for determining the saving available but this was all based on the assumption that the saving increases uniformly with the superheat, which, however, is not borne out by the author's experience, as a notable saving is not realized with less than 100 degrees of superheat, and above that point it increases very rapidly.

[Following this Herr Garbe considers the subject of compounding vs. superheating and then discusses the different designs of superheaters and gives some details of locomotives using superheated steam. The series closed with the account of a number of comparative tests. We will publish an abstract of these chapters in a later number.—ED.]

EXAMINATION FOR APPRENTICE DRAFTSMEN, U. S. WAR DEPARTMENT.—The U. S. Civil Service Commission announces that an examination will be held on March 4, 1908, at all of the more important cities of the United States, to secure eligibles to the position of apprentice draftsmen, to fill vacancies in the War Department. These positions pay from $30 to $60 a month and an apprentice may enter an examination for the position of draftsmen, where the salary to start is from $1,000 to $1,200 a year. The age limit is from 17 to 21 years.

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A resolution was passed at the last meeting of the New York Railroad Club requesting the committee on subjects of the M. C. B. Association to bring the subject of standardization of parts of all steel cars up for consideration at the convention. This resolution grew out of the recommendation in Mr. A. M. Waitt's paper, and while the suggestion is not by any means new, it appears as if the time had arrived when some real action could be taken upon it.

The desirability of such standards is being more thoroughly appreciated as steel cars are becoming more numerous. When a steel car is damaged sufficiently to require it to be sent to the repair yards of a foreign road, it usually is in a condition to need some new parts and if, as is often the case, it differs greatly from the cars on the road doing the repairing, the delay in obtaining the proper shaped and sized parts is very serious and most aggravating to all concerned.

SUPERHEATERS.

Herr Robert Garbe, privy counsellor of the Prussian State Railways, has probably had a longer and more thoroughly practical experience with locomotive superheaters than any other railway man on either continent. While his published works give in great detail the results of his observations on locomotives and locomotive appliances, a series of articles which he recently contributed to the *Engineer* (London) on the subject of the application of highly superheated steam to locomotives, presented the matter connected with superheated steam in a comparatively brief and very clear-cut manner. These articles give the author's ideas on each separate phase of the subject and briefly recount reasons for his deductions. An abstract of part of this series of articles is given in this issue for the benefit of such of our readers as do not have access to the *Engineer.*

It will be seen that Herr Garbe does not consider steam to be superheated in the real sense until it is at least 180 degrees F. above the saturation temperature for the pressure. His experience has shown that below this point there is a very rapid falling off in the advantages to be gained. The fact mentioned, that a locomotive on the Prussian State Railways with steam superheated to this temperature was capable of developing 40 per cent. more power than a similar sized saturated steam compound locomotive, which power was obtained with 10 per cent. less fuel consumption, is a feature which is worthy of the most careful consideration.

DESIGN OF WALSCHAERT VALVE GEAR.

The Walschaert valve gear has passed through its trial period in this country and is now being generally applied to all middle and heavy weight power. There is no need to recount its advantages, as they are now too well known to every one to require comment. There is need, however, for our locomotive designers and draftsmen to give special heed to the details of this gear, as they will no doubt be required to design it for application to practically all types of locomotives.

As is natural in applying an entirely new arrangement, the first attempts left considerable to be desired. Although the Walschaert valve gear had been in use abroad for a great many years, and its details there have been fully perfected, that fact proved to be of small value to us and the first attempts, based largely on foreign practice, were not altogether suited to our conditions. It has been necessary to strengthen, stiffen and simplify each successive application as the weak points have been developed by the very hard service under American conditions, intensified by serious traffic congestion. We believe now, however, that this period has passed and the present designs of this gear being applied have eliminated all of the serious shortcomings and can safely be taken as a basis and guide for the evolving of designs in the railroad drafting rooms. In this issue we are giving most of the important details of two different designs of the gear, one from each of the larger locomotive companies, both of which we believe to be good examples. In an earlier number we gave

similar details from a design on the Canadian Pacific Railway, in which it replaced the Stephenson gear on a standard locomotive, which conditions introduced many difficulties not present when the whole locomotive is being designed.

The three most important features of this type of gear, after the general arrangement has been laid out to give the best movement of the valve, are found in the necessity for providing as rigid a support as possible, in the provision for reducing wear to a minimum, and in providing sufficient lubrication at every point.

VANADIUM IN CAST IRON.

The improvement in the quality of steel by the addition of a small amount of vanadium has been given a great deal of attention by metallurgists and steel makers during the past year and the increased strength and non-fatiguing qualities of this material are now pretty generally known. There has not, however, appeared very much information concerning its effect on cast iron. It is but fair to assume that the action of vanadium on cast iron would be very similar to that on steel and if that actually proves to be the case, as seems evident, the field for improvement will be greatly extended. About the only figures from tests on cast iron that have come to our attention are found in a paper by Mr. Richard Moldenke, secretary of the American Foundrymen's Association, which are given in abstract on page 115 of this issue. While these are somewhat preliminary experiments they show that it is possible to increase the breaking strength of good machinery iron from 2,000 to 2,500 lbs. and of white iron from 1,500 to 3,900 lbs. These, of course, are wonderful results and if but one-half of the improvement can be obtained in regular foundry practice, the value to railroads and manufacturers will be exceedingly great. The largest field of usefulness of such iron would seem to be the cast iron wheel where, in spite of the recent increase in the thickness of the flange, there is still much room for improvement. Its possibilities in connection with locomotive cylinders, valve bushings and rings are also very attractive, as experience seems to indicate that the wearing qualities and the ability to take a high glazed finish while at the same time being soft and easy to machine, are present to a remarkable degree. Experiments in this field are now being carried on by one of the locomotive companies.

Ferro-vanadium in commercial shape ready for use in the foundry can now be obtained in practically unlimited quantities and at a price which will not prohibit its very general use.

A very costly conflagration occurred recently at one of our latest and best equipped locomotive terminal plants, in which the fire started in a shop structure between the two roundhouses and spread with great rapidity to the roofs of the latter. At this time both houses were filled with locomotives, some of which were under steam, and the final result was that sixteen locomotives were destroyed as far as fire can destroy them. Although this fire spread with unusual rapidity there was time to have saved a good portion of these engines had it not been for the fact that both turn-tables were put out of commission within a few minutes after the fire started. These turn-tables were driven by electric motors and obtained their power from wires which were run along with the lighting and other power circuits, on a row of short supports on the roof of the houses. These roofs being of wood soon caught fire, the wires were melted, and the operation of the turn-tables stopped.

This is not an unusual condition in roundhouses operated by electric turn-tables and is one which should be immediately corrected at all points. It is a simple matter to put the wires running to these turn-tables and motors underground and at the same time that this is being done a motor driven capstan or reel should be provided on each turn-table, so that in case of fire, engines which are not under steam could be drawn on to the table. This arrangement would also, no doubt, prove to be very valuable at other times for moving dead engines, tanks, etc.

PRACTICAL WORK IN CONNECTION WITH COLLEGE TRAINING.

To the Editor:

I have read with much interest the editorial in your January number, entitled, "Practical Work in Connection with College Training." My own experience has shown me the importance of work in the shop, or office, as a preliminary to teaching, or executive work. I have found the lessons learned during the five years which I spent as a machinist, before and after entering college, of almost incalculable benefit. An interregnum of three years in my college work, when I was assistant manager of a large manufacturing company in the east, opened up another field of valuable experience. I believe the fact is coming to be more generally recognized, that one who is teaching or leading young men along the ways of engineering should have traveled those ways with his own feet.

This is a natural reaction from the old idea of the college professor who was necessarily an indoor plant carefully kept from exposure to the rude blasts of the practical and business world. Nearly all of the engineering teachers at the Case School, and of those with whom I am acquainted here, have regular outside work in addition to their college duties and are employed as consulting engineers and experts with full recognition of their qualifications for such work. When there is this feeling in the engineering faculty, it is pretty sure to be communicated to the student body, giving a stimulus there towards good, sound, practical training.

I know that the majority of the students at the Case School, especially in the upper classes, found practical employment during vacations in shops and offices, as far as was possible, and that many of the men entering the institution were already good workmen in either wood or iron. Since reading your editorial, I have been interested in getting statistics with regard to the class which graduated here in 1907 and I enclose a list showing the total number and the record of outside experience. There are two or three in the list who would not be regarded as having had experience which would be particularly helpful in the line of the profession, but the great majority have used their opportunities wisely.

CLASS OF 1907.

Number in Class	85
Number having had practical experience	65
Number of years experience:	
8 years and over	3
7 years	1
6 years	2
5 years	2
4 years	5
3 years	6
2 years	7
1 year and over	19
6 months and over	19
Nature of practical experience:	
Shop and drafting room	12
Drafting	3
Railway shops	23
Teaching and farming	2
Salesman	2

Other occupations, each represented by one student, were as follows: Machinist; concrete inspector; chemical laboratory; engineer, draftsman and telegraph operator; telephone work; bridge work and concrete construction; chemist; farming; manufacturing; lumber mill; bookkeeper; mail clerk, machinist, helper and farm hand; locomotive firing, drafting and farming; clerk; automobile work; civil work and shop; test department; shop and farming; shop and power plant; ranching.

A card index is kept of the Seniors and these figures are made up from the statements of the students themselves. I have no reason to doubt their reliability, and they show a state of things quite similar to that at Cornell. These men were mechanical engineers, but I have no doubt that a somewhat similar record could be made for those in the other engineering schools.

I well remember an address delivered by the late Professor Thurston, at one of the Case School commencements, in which he strongly advised the graduating class to take at least one year of postgraduate work. He concluded by saying: "I do not mean another year in college, but I mean for you to put on your jumpers and overalls and spend at least one year in contact with actual things in the shop." C. H. BENJAMIN.

Purdue University, Lafayette, Indiana.

FOUR CYLINDER SIMPLE LOCOMOTIVE—GREAT NORTHERN RAILWAY OF ENGLAND.

FOUR CYLINDER SIMPLE LOCOMOTIVE.

GREAT NORTHERN RAILWAY (ENGLAND).

CHAS. S. LAKE, A. M. I. MECH. E.

Among British railways the Great Northern is by far the largest user of the Atlantic (4-4-2) type of locomotive and to Mr. H. A. Ivatt, locomotive superintendent of that road, belongs the credit of having been the first to introduce the type in the United Kingdom.

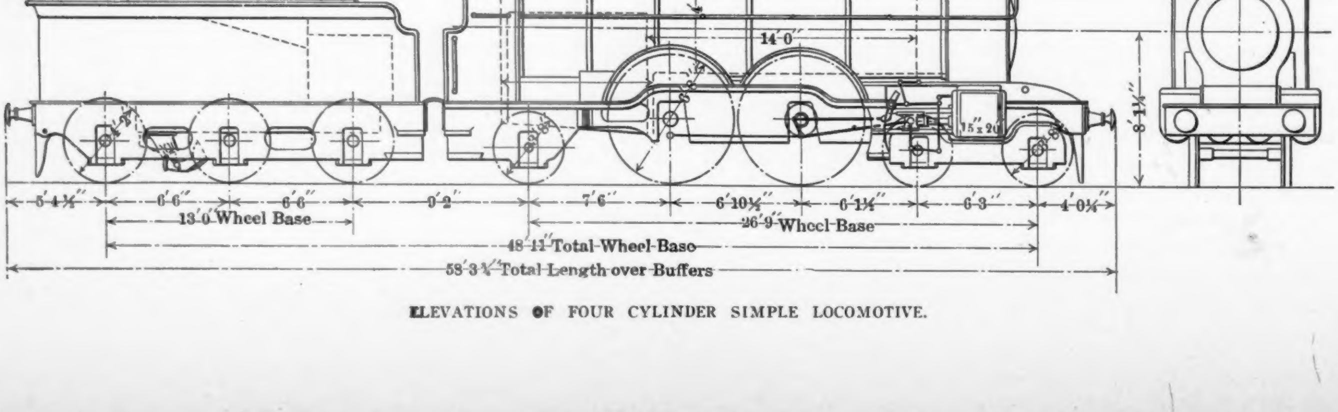
This was in 1898, at a time when all other locomotive engineers in Great Britain were striving their utmost to retain the eight-wheeled, "American type" engine in the front rank for express passenger traffic working. Mr. Ivatt numbered his first Atlantic locomotive "990" and gave it two simple cylinders 18¾ in. diameter by 24 in. stroke, coupled wheels 6 ft. 8 in. diameter, total heating surface 1,442 sq. ft. Grate area 26 sq. ft. and working pressure 175 lbs. per square inch. Although, judged from the locomotive standards of the United States, this would be considered a small engine, it nevertheless created a great impression in English railway circles at the time, principally, of course, on account of the departure which had been made from previous practice in the matter of type. The standard express locomotive of the largest class on the English Great Northern Railway at the present time is that known as the "251" class; simple, Atlantic type, with 5 ft. 6 in. diameter boiler and wide firebox, having a total heating surface of 2,500 sq. ft. and 30.9 sq. ft. of grate area. The proportions of the cylinders, wheels, etc., remain as in the "990" engines, which appear above.

One locomotive belonging to the "990" series and also one of the "251" engines have been built with four cylinders. In the first case the cylinders work single-expansion and in the second they are compounded. Engine No. 271 with four simple cylinders is, by Mr. Ivatt's courtesy, illustrated herewith. It is the only Atlantic locomotive in use on the Great Northern in which the forward coupled axle is exclusively employed for driving purposes. When this engine was first built, viz., in 1902, it was fitted with two sets of Stephenson link-motion only, for working the four slide-valves, which were of the piston type, and it ran in that condition for a considerable time. Later, in 1905, it was taken into the Doncaster shops of the G. N. Company and fitted with new cylinders having their valve chests above and independent valve motion for each valve.

The accompanying photographs and drawings show the engine as altered and at present running. The cylinders are cast in pairs together with their valve chests and passages, and are arranged in line across the truck center, the inside ones driving the crank-axle and the outside ones crank-pins in the leading drivers.

The slide-valves are of the open-backed, balanced type allowing of a free passage for the exhaust and thus reducing the tendency towards back-pressure at high speeds. The slide-valves of the inside cylinders are worked by Stephenson link-motion through rocker arms and those of the outside cylinders by the Walschaert's gear. Two reversing shafts are provided, one for the Stephenson gears and the other for the Walschaert, the same reach rod, screw, and handwheel, however, operating all four gears. The reversing shaft of the inside valve motion carries a coiled spring instead of the usual counterweights for neutralizing the weight of the link and its attachments.

The inside and outside cranks on each side of the engine are set 180 degrees apart and at 90 degrees in relation to the opposite pair of cranks, so that the two pistons on each side are always moving in opposite directions and there is a crank pin on every quarter. The main-rods are all of equal length, viz., 5 ft. 9¾ in. between centers and the throw of all cranks is 10 in. The crank-axle has journals 9 in. long by 8½ in. diameter and its

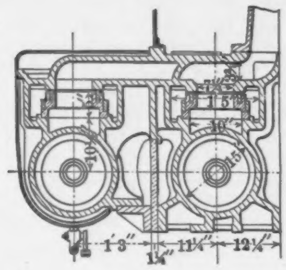


ELEVATIONS OF FOUR CYLINDER SIMPLE LOCOMOTIVE.

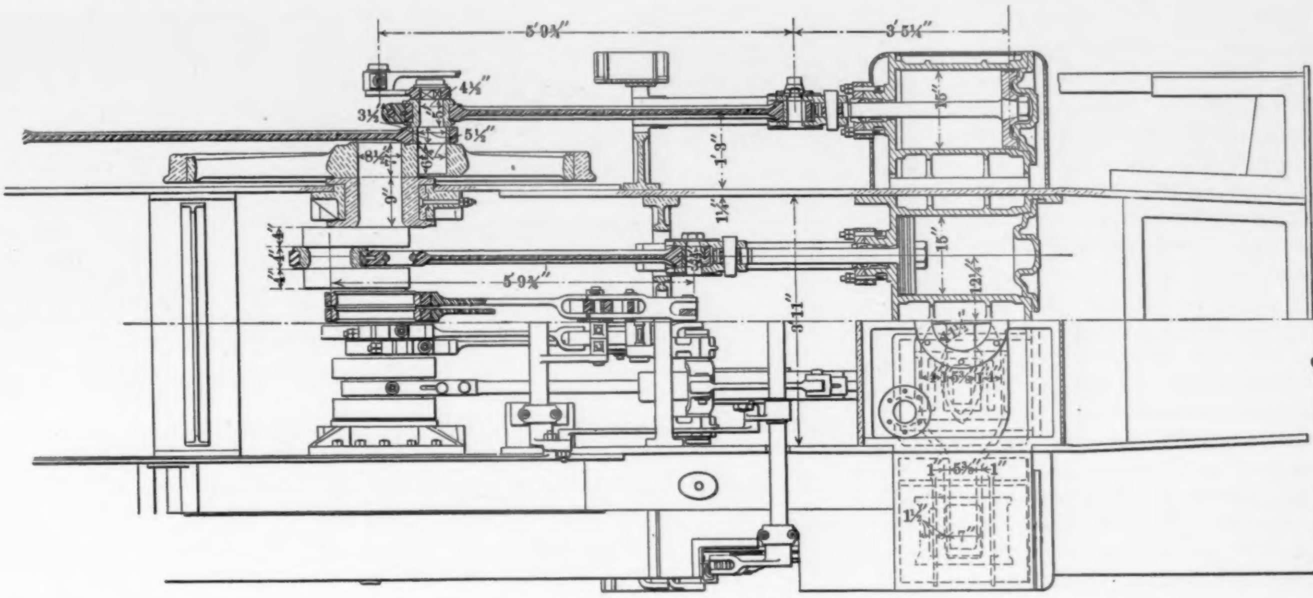
diameter at the central portion, between the two inside crank webs, is 7 in.

The crank webs are of the circular or disc pattern, with a diameter of 1 ft. 8¾ in. and a uniform thickness of 4 in. The distance between centers of journals is 3 ft. 9½ in. and between centers of inside crank pins 2 ft.. ½ in. The distance between centers of inside cylinders is 2 ft. ½ in. and the corresponding dimension for the outside cylinders is 6 ft. 7½ in.

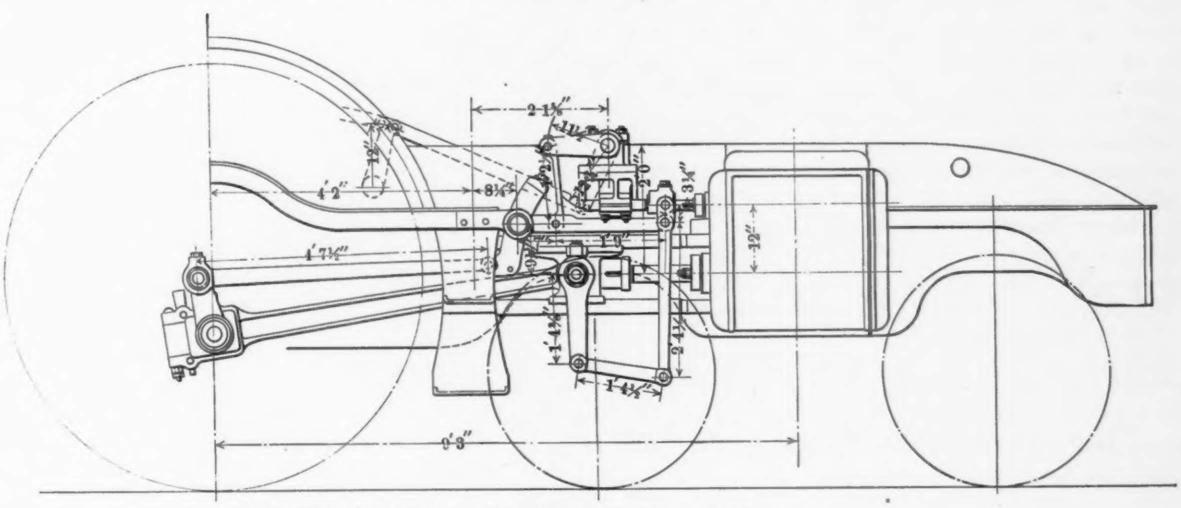
The front engine truck is of the swing-link type and lateral play is provided in the horn cheeks and boxes of the carrying wheels under the foot-plate which, unlike all the other wheels of the engine, have outside framing and axle boxes.



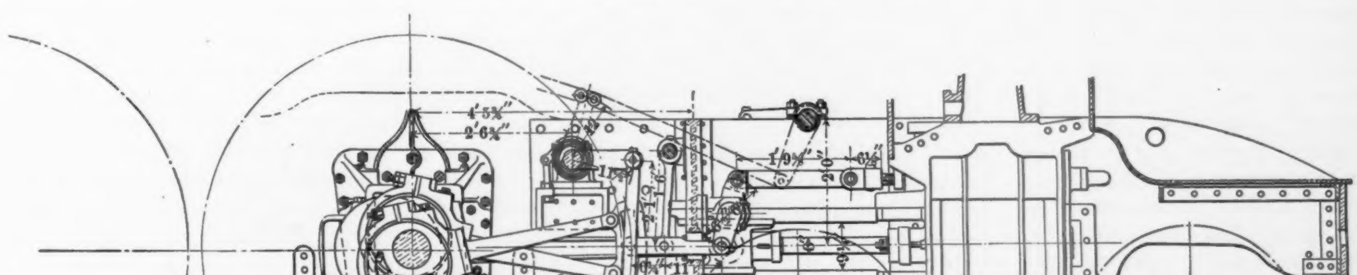
CROSS SECTION OF CYLINDERS.



PLAN AND LONGITUDINAL SECTION OF RUNNING GEAR.



ELEVATION OF OUTSIDE CYLINDERS AND VALVE GEAR.



ELEVATION OF INSIDE CYLINDERS AND VALVE GEAR.

The cylinder area of this engine is equal to that of two 21¼-in. diameter cylinders and the tractive effort is 113 lbs. to every 1 lb. of effective steam pressure on the pistons.

The boiler barrel and firebox outer shell are built of steel throughout and the interior firebox is of copper, radial stayed, with three expansion rows at the throat plate end of the crown sheet.

The front tube sheet is recessed back into the barrel for a distance of 1 ft. 11¼ in. from the forward extremity of the barrel. The boiler has a diameter outside of 4 ft. 8 in. and a length between tube plates of 14 ft. It is mounted with its axis 8 ft. 1¼ in. above rail level. The top of the firebox outer shell is semi-circular in shape and the extreme length over the firebox casing is 8 ft. The tender is of the Great Northern standard pattern on six 4-ft. 2-in. diameter wheels. It is fitted with water scoop actuated on Mr. Ivatt's patent hydraulic principle and carries 5 tons of coal and 3,670 gallons of water.

The engine is employed for working express passenger traffic on the Great Northern main line whereon speeds rule high and train weights, in the principal services, are unusually heavy for British railways. It has given every satisfaction in working, but no further locomotives of the same type have yet been built. The writer has had frequent opportunities for noting the performance of No. 271 and has invariably found the engine renders good service even with the fastest and heaviest trains. Still, no better results are obtained than from the larger boilered two-cylinder Atlantic type engines of the "251" class, which are, of course, more economical to maintain owing to their fewer parts. The coal consumption is about the same in both cases, but No. 271, as might be expected, uses more oil than its two-cylinder contemporaries.

The leading dimensions are as follows:

GENERAL DATA.

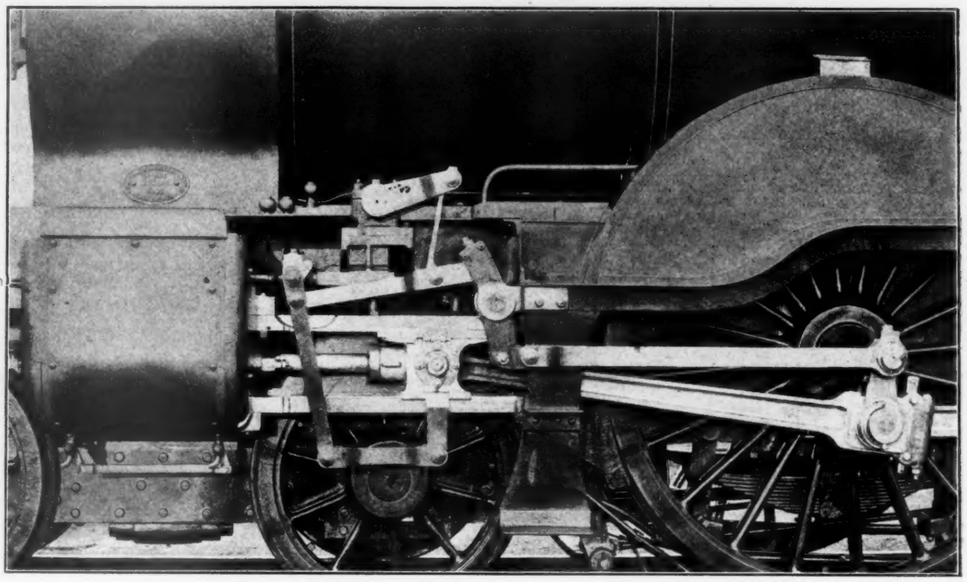
Gauge	4 ft. 8½ in.
Service	Passenger
Fuel	Bit. coal
Tractive effort	16,800 lbs.
Weight in working order	138,880 lbs.
Weight on drivers	79,520 lbs.
Weight on leading truck	34,720 lbs.
Weight on trailing truck	24,640 lbs.
Weight of engine and tender in working order	230,496 lbs.
Wheel base, driving	6 ft. 10½ in.
Wheel base, total	26 ft. 9 in.
Wheel base, engine and tender	48 ft. 11 in.

RATIOS.

Weight on drivers ÷ tractive effort	4.75
Total weight ÷ tractive effort	8.25
Tractive effort × diam. drivers ÷ heating surface	1,030
Total heating surface ÷ grate area	54.2
Firebox heating surface ÷ total heating surface, per cent	10.8
Weight on drivers ÷ total heating surface	61
Total weight ÷ total heating surface	106
Volume four cylinders	8.2 cu. ft.
Total heating surface ÷ vol. cylinders	159
Grate area ÷ vol. cylinders	3

CYLINDERS.

Number	4
Kind	Simple
Diameter and stroke	15 × 20 in.
Kind of valves	Bal. slide



VIEW SHOWING VALVE GEAR—FOUR CYLINDER SIMPLE LOCOMOTIVE.

WHEELS.

Driving, diameter over tires	80 in.
Driving journals, main, diameter and length	8½ × 9 in.
Engine truck wheels, diameter	44 in.
Trailing truck wheels, diameter	44 in.

BOILER.

Style	Straight
Working pressure	175 lbs.
Outside diameter of first ring	54 in.
Tubes, length	14 ft.
Heating surface, tubes	1,162.75 sq. ft.
Heating surface, firebox	140.25 sq. ft.
Heating surface, total	1,303 sq. ft.
Grate area	24.5 sq. ft.
Center of boiler above rail	97¼ in.

TENDER.

Weight	91,616 lbs.
Wheels, diameter	50 in.
Water capacity	3,670 gals.
Coal capacity	5 tons

THE ERA OF STEEL IN CAR CONSTRUCTION.

Mr. Arthur M. Waitt presented a very interesting and comprehensive paper on the subject of "The Era of Steel and the Passing of Wood in Car Construction" before the January meeting of the New York Railroad Club. The paper opened with a brief review of the history of the steel car and a consideration of its length of life, following which were some very striking figures on the growing shortness of the lumber supply, the influence of which is even now being felt. Following this Mr. Waitt spoke in part as follows:

"At the present time there are three distinctly different theories and systems in connection with the design for steel cars, each supported by able advocates. With one system the designers endeavor to carry the load on the side sills, using the center sills for buffing only. Another school of design endeavors to distribute the load nearly equally over all the sills. This design necessitates a somewhat heavier construction of car than the former. The third school of designers, which have the support of several car builders, endeavor to carry the load largely on the center sills, which are made very deep (even up to thirty inches); the center sills thereby not only carry the load but are also exceptionally strong to resist buffing.

"With the rapid introduction of steel car framing and its permanence in future practice, it seems at this time desirable as far as possible to eliminate the present great diversity of designs; for such diversity makes it impossible to keep the necessary parts in stock, for interchange repairs in the shops and repair yards of the various roads in the country. Not only is it desirable to simplify and eliminate this great diversity of design, but there are also many strong arguments for working toward a body framing in freight cars, which will permit of an underframing that is interchangeable for box cars, gondolas and flat cars. The system of body framing which carries the load largely on the center sills seems to have a basis which will readily make it possible to have the body framing interchangeable as above suggested.

"Much has been done in years past toward unifying and simplifying the design of wooden cars, and it would seem that sufficient experience has now been had with cars of all-metal construction, or at least of all-metal underframing, to warrant a determined step toward standardizing.

"It would seem desirable for the Master Car Builders' Association to devote considerable attention in the near future to eliminating these great differences in design and the unnecessary multiplicity of parts, and to lend its influence through its

recommendations toward greater uniformity in sizes and greater simplicity in design.

"It seems perfectly feasible at this time to adopt as recommended practice and later as standards some rolled and pressed sections, at least in the main members of the body framing. A move in this direction would before long be felt in increased simplicity and economy in interchange repairs. It would seem even possible at this time to adopt standards in lengths and widths for steel box, gondolas and flat cars, and then as a natural sequence many standard shapes and sizes would follow. It would also be practicable to standardize many of the rolled sections for angles and channels which are used in the superstructure of many styles of cars now being constructed.

"In freight and in passenger car construction during the development period in the past the cars were strengthened where found necessary and all sorts of makeshift methods and devices, such as truss rods, flitch plates, and the introduction of malleable for cast iron were made use of. All this was done to make the car stand up in service, with their increasing size, and the increased severity of the work imposed upon them. All these expedients proved ineffectual and unsatisfactory, and at this time the needs of our present-day service can only be met by a car with a steel body framing.

"During the past year one prominent road in the country has designed and constructed box cars with not only a steel underframing but also with a steel superstructure. This is a daring attempt to further develop 'the era of steel' for car construction, but the practice is one which would seem to be open to decided doubt as to the entirely satisfactory results that will be obtained in service. On first impression the observer might assume from the description or examination of the all-steel box car that it was in every way a decided advance step. It is to be hoped that railroads will very carefully consider the history of steel box cars both abroad as well as at home before going very heavily into their construction.

"In the construction of gondolas and flat cars, except where such cars are likely to be used in service for hot cinders, hot billets, or some similar lading, it would seem to the writer the wisest policy to use a wooden flooring rather than steel.

"With now some ten years of extensive use of steel underframe and all-steel freight cars the earlier arguments in favor of their almost universal adoption have been strengthened and broadened. Even if the lumber supply was likely to be ample in the future, there can be little justification in perpetuating the wooden car, either by large continued expenditures for the maintenance of light capacity cars or by ordering cars with a wooden body framing for present or future use.

"In a paper read before the New England Railroad Club in 1904 by Mr. John H. MacEnulty, the writer stated that: 'It has been determined by two of the largest railway systems of the country that the drawbar pull required to move a ton of freight in a properly constructed car of 100,000 lbs. capacity is 24 per cent. less than that required to move the same load in an average wooden car of 60,000 pounds capacity.'

"This is not only a strong argument in favor of steel car construction, but also for the use of large capacity cars.

"Ease of renewal of the worn or broken parts in cars of steel construction is a feature of considerable advantage in favor of such cars as compared with those made of wood.

"Another great advantage from the use of steel cars or cars with steel underframe in freight service is developed when trains are wrecked; for steel cars in wrecks withstand successfully punishment which would mean the total destruction of wooden cars. It has been found that the parts bent or torn in damaged steel cars can be readily renewed or put back in their original shape at a comparatively reasonable cost.

"Wooden cars are damaged yearly in large numbers to an extent which makes them unfit for service and not worth repairing. With steel cars such a condition is practically impossible."

"The cost of steel cars per ton of hauling capacity in general is less than with wooden cars. In wooden cars of high capacity it is found that the ratio of light weight to the carrying capacity is altogether too high for comparison with steel cars, if viewed from the basis of economy in operation.

"In cost of maintenance the steel car has a decided advantage. In meeting the requirements of service in the operating department again the steel car is decidedly the favorite. Steel cars are so much less liable to damage in service that in many cases where a wooden car would be rendered unfit to continue in use, a steel car will be free from any serious defects and will continue as a money earner and not become a money loser.

"The life of wooden cars built to-day must necessarily be shorter than those built fifteen years ago, for at the present time it is impossible to get lumber anywhere approaching in quality that which was required in first-class freight cars in 1892.

"Trains are now frequently being made up containing from sixty to eighty or more heavily loaded cars, weighing from 3,000 to 4,000 tons, and the severe service and strains to which the cars are subjected make the cost of necessary repairs to the wooden cars increase constantly. On roads having such heavy traffic and handling such long trains, or whose cars are likely to be handled in such trains, they can ill afford to spend much money for the heavy repairs and maintenance of wooden freight cars of under 60,000 pounds capacity, and it is clearly no longer profitable to build such cars, which are necessarily too lightly framed to operate in conjunction with the heavy capacity steel car.

"As showing the conclusions arrived at, on one of the prominent railway systems of the country, the writer has before him the report and recommendations made to the chief executive officer of the company at a recent date. The report recommends the retiring of 4,600 coal and coke cars ranging from nine to twenty-three years in age, and having from 40,000 to 60,000 pounds capacity.

"It was shown that these cars average a cost of $95.98 per year for repairs, or 37.8 per cent. of the average total value of the cars. The tonnage of these cars being compared with tonnage of new steel cars which have been used by the company in large numbers, when considered in connection with the first cost and the cost of maintenance of steel cars, and based on experience, showed conclusively that the company could buy 3,000 new steel cars having a total capacity 20 per cent. greater than that of the 4,600 wooden cars, and out of the amount that it would cost to maintain the wooden cars for one year they could pay 6 per cent. interest on the cost price of the new steel cars and have remaining over $215,000. A desire for the greatest economy for the owners of the roads will assure the substitution of a lesser number of larger capacity steel cars for old light capacity wooden ones.

"Although steel underframing and practically all-steel construction has been used for a number of years for about all of the various types of freight equipment, yet it is only during the past three years that much has been done in this country to adapt such construction to the various styles of passenger equipment.

"Very satisfactory designs have been developed for baggage and postal cars, as well as for suburban and regular passenger service, and within the past year also for Pullman sleepers. It is yet too early to predict the outcome, but it seems to the writer that in future development of the design for steel passenger equipment cars there may be a happy medium arrived at, and generally adopted, where the underframes and the superstructure framing will be of metal, but a reasonable use be made of wood or some fireproof substitute, other than metal, which will permit of a decorative treatment that is more pleasing to the eye than is the case where thin metal is used, and which will also have all of the reasonable and necessary elements of safety for those who entrust their lives in such cars.

"In the early days of steel cars the matter of repairs was looked upon with many misgivings by the average master car builder and car repair foreman. Experience in handling these cars in large numbers has shown that there was no cause for any uneasiness on this score. In the repairs of steel cars it is not necessary to employ specially trained labor, and very few extra tools or facilities are absolutely necessary, though, of course, a

few especially adapted tools and appliances will greatly facilitate the work. On roads having large numbers of steel cars in service it has been found that not more than one-half of one per cent. of this equipment need be out of service at any one time, needing repairs, while in the case of wooden cars from two to four per cent. is not unusual."

Mr. G. R. Henderson, in discussing the paper, and referring particularly to the design of steel car mentioned, which carries all of the load on the center sill, said in part: "This must depend very largely upon the type of car. Where we have a car with sides eight feet high there is a great strength available to support the load. I think under conditions like that it would be manifestly unwise to design our cars so that the entire load is carried on the center sills.

"When you consider a hopper car with the deep bolster possible, you will see that there is no difficulty whatever in transferring the strain from the side sill to the center plate of the car. In other words, the design of the car should be made according to the service for which it is intended.

"I think that this Club should initiate some action toward unifying the construction of steel cars. I do not know of any better way than for this Club to suggest this subject to the Master Car Builders' Association committee as subjects for action at the meeting of the Association next summer.

"It is important that the standard sizes be amply strong. I would like to read the specifications for sills of fifty-ton steel hopper and flat cars which I prepared some time ago.

"For hoppers, the body is to be proportioned for carrying 125,000 pounds uniformly distributed between bolsters, in addition to the dead weight of the car.

"For flat cars the sills are to be proportioned for carrying 125,000 pounds uniformly distributed in addition to the dead weight and also for 75,000 pounds concentrated on a line across the car at any point between the bolsters, the side sills being considered as carrying the same proportion of load as the center sills, to allow for concentrated applications in loading heavy objects.

"In both types of cars the center sills and draft attachments must be proportioned for a force of 100,000 pounds pulling, and 200,000 pounds buffing and strains due to either or both the horizontal forces and the vertical loading combined must not exceed 12,000 pounds per square inch in tension (net section), or 12,000 — l/r in compression where l = the length and r = radius of gyration both in inches. The maximum rivet shear must not exceed 8,000 pounds per square inch, and the rivet bearing 16,000 pounds per square inch.

"I would merely call attention to the fact that some years ago there were wooden hoppers of thirty-ton capacity which, I think, weighed about 30,000 pounds. Now, if you take the present designs, you will find that they run about 40,000 pounds, so that with the one-third more weight per car we get two-thirds more carrying capacity. I think that is well worth the extra expense, when you take into consideration a great many other points in favor of the larger cars.

"In the early part of last year we obtained bids on steel cars and the prices ran a little less than three cents per pound. You can get very little structural steel erected for less than four cents a pound, and even at that price very few people would think of putting up a wooden building nowadays. In the long run the saving on the steel car is certainly very large and it seems to me that it is perfectly logical that the railroad companies should put up steel cars rather than to continue their old wooden cars on side tracks and hold them there for months for repairs."

Mr. W. R. McKeen, Jr., in a written discussion included some very interesting recommendations as follows:

"Personally I consider it a mistake to build any more wooden freight or passenger cars. Having decided to use steel for car structures it is a mistake to use the same methods and designs of framing and to maintain the general exterior and interior appearances of the wooden car.

"The design of steel car should be consistent with the material used, the idea being to obtain the maximum efficiency of the steel as a structural material. The character of material steel being so entirely different from that of wood, a great many advantages and possibilities are obtainable in a steel car design which were impossible with wooden cars. Because steel is used for cars, is no reason why there should be a material increase in weight; my opinion is that it should decrease the weight."

Suggestions for steel passenger car structures:

"Round roof, with its strength, economical features of weight and construction.

"Induced or mechanical ventilation obsoleting the gravity system; providing intake of fresh air at the floor of car; suction or exhaust ventilation at the top.

"All latterly disposed steel should be utilized for strengthening the car frame in resisting shock, including side sills, plates, steel side, braces, etc. Sufficient area of cross section provided in center sills for small or ordinary shocks.

"End construction such as to preclude the possibility of telescoping."

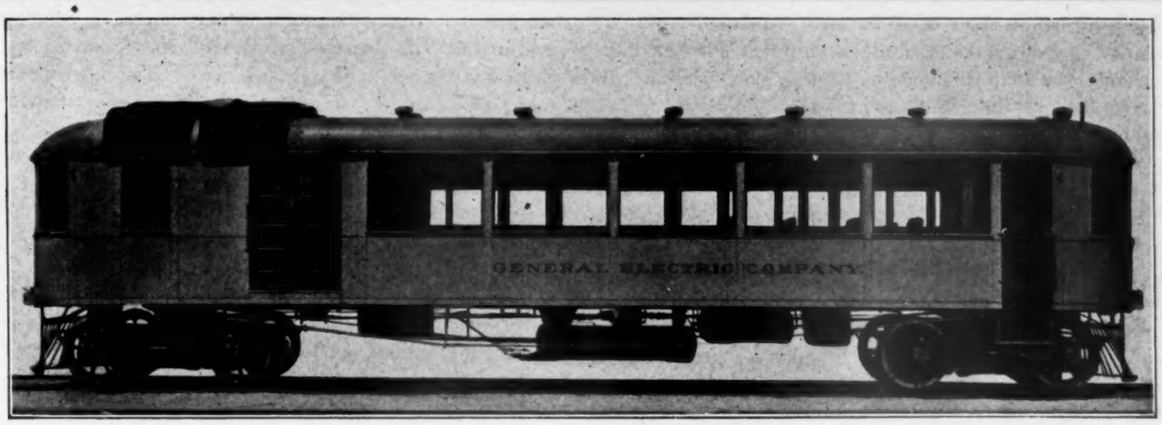
Change in British Patent Laws.—Consul-General Wynne, of London, in referring to the new British patent law, which goes into effect on January 1, 1908, quotes the following, which will be of direct interest to American machinery builders: If a patented article or process be manufactured or carried on exclusively or mainly outside the United Kingdom, then, unless the patentee prove that the patented article or process is manufactured or carried on to an adequate extent in the United Kingdom, or give satisfactory reasons why it is not so manufactured or carried on, the comptroller may make an order revoking the patent forthwith, or he may make an order revoking it after a specified interval if the patented article or process be not in the meantime adequately manufactured or carried on within the United Kingdom; but in the latter case, if the patentee give satisfactory reasons for the failure so to manufacture or carry on within the prescribed time, the comptroller may extend the period by not more than one year. To obtain such an order, application must be made to the comptroller at least four years from the date of the patent and one year from the passing of the act; moreover, any decision of the comptroller is to be subject to an appeal to the High Court, and no order is to be made that will be at variance with any treaty, convention, arrangement, or engagement with any foreign country or British possession.

ANNUAL COST OF POWER PER BRAKE HORSE-POWER.*

B. H. P. of Unit.	Steam.	Electricity.	Gas.	Gasoline.
1	$600.00	$312.50	$380.00	$487.50
2	500.00	282.00	312.50	416.00
3	437.50	252.00	260.00	350.00
4	375.00	227.50	220.00	300.00
5	320.00	207.50	192.50	262.50
6	280.00	192.00	172.50	240.00
7	250.00	179.00	160.00	210.00
8	230.00	168.00	152.50	182.50
9	210.00	158.00	145.00	165.00
10	195.00	152.00	140.00	152.00
12	175.00	140.00	132.50	137.50
14	165.00	133.00	126.00	122.00
16	157.50	128.00	120.00	112.50
18	150.00	126.00	116.50	107.50
20	146.00	123.00	113.00	102.00
22	140.00	121.50	110.00	98.00
24	137.50	119.50	107.50	95.00
26	133.00	117.50	105.00	92.50
28	130.00	116.50	102.50	90.00
30	127.50	115.00	102.00	87.50
35	124.00	113.50	100.00	85.00
40	120.00	112.00	98.00	82.50
50	112.50	110.00	96.00	80.00
60	105.00	108.00	94.00	78.00
70	100.00	106.00	92.00	76.00
80	95.00	104.00	90.00	74.00
90	90.50	102.00	88.00	72.00
100	86.40	100.00	86.00	70.00

* Unit costs: Coal, $5 per ton; electricity, $0.135 per K. W.-hour; gas, $1.20 per 1,000 cubic feet, at 760 B. T. U.; gasoline, $0.20 per gallon.

—*William O. Webber, in Engineering News.*



GASOLINE ELECTRIC RAILWAY MOTOR CAR.

GASOLINE-ELECTRIC MOTOR CAR FOR RAILWAY SERVICE.

The General Electric Company has been studying the problem of designing a satisfactory independently driven motor car for railway service for several years. After careful consideration and a study of all the cars in operation, it was decided that a car propelled by electric motors connected to the axles, the current being obtained from a generating plant aboard the car, was the most satisfactory and promising type of construction. This arrangement permits the greatest ease and flexibility in control of the speed and power of the car and eliminates many structural problems present with both the direct gasoline or steam driven type.

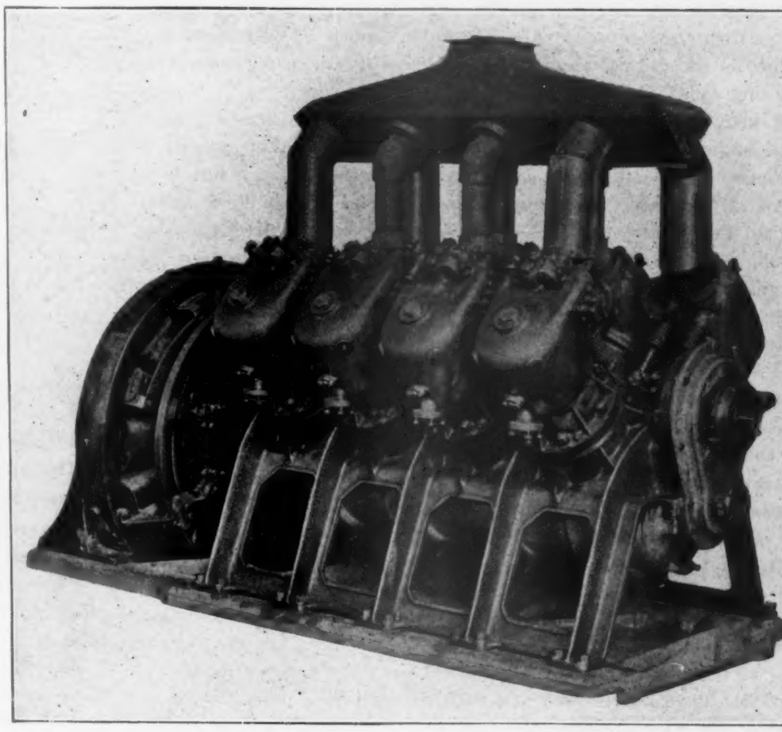
About two years ago this company finished a car which it had designed for service on the Delaware & Hudson Railway. This car was illustrated and described on page 88 of the March, 1906, issue of this journal. It resembled a standard passenger coach in appearance, was 65 ft. long, carried 40 passengers and weighed about 65 tons. It was mounted on specially designed trucks, which carried two ordinary railway motors, such as are in general use on the Interborough Railway in New York. The car contained a six-cylinder horizontal opposed gasoline engine of 160 brake horse-power, which was direct connected to a 120-k.w. General Electric generator designed for 600 volts.

This car was operated and thoroughly tested out and while it did not prove a commercial success it nevertheless served as a most valuable experiment in showing exactly where improvements should and could be made.

From the results of the operation of this car the General Electric Company has designed and built another car of the same general type, which is now in operation. This car measures 50 ft. in length, instead of 65, it will carry 44 passengers instead of 40 and weighs, fully equipped, but 31 tons as compared with 65 tons for the other car. The car body is built of steel throughout, with the exception of the interior finish, and a specially designed and much lighter type of truck has been used. An entirely new design of gasoline engine having eight cylinders, and weighing very much less than the English engine with six cylinders used in the other car, has been designed. The generator is also extremely light for its capacity and the resulting combination appears to be most satisfactory in every way. The car is capable of comparatively high speeds, having maintained on its test run a speed of 50 miles per hour on a level track and 47 miles per hour on a rising grade.

The car body is designed throughout with special reference to the service required, the main object in view being to secure a maximum carrying capacity with a minimum weight, while at the same time not neglecting the matter of structural strength and durability. The shape of the ends of the body has been made semi-circular and a plain oval shape roof is used which permits of great strength with minimum weight and greatly reduces the air resistance. The underframe consists of two 6-in. I-beams as center sills and 6-in. channels as side sills. These are braced diagonally to give stiffness and are further strengthened by a number of cross beams between the bolsters. Truss rods are fitted to each of the side sills. The superstructure of the car is built on T-irons bent in U-shape and forming, in one piece, the side posts and the carlines. The sheathing is of steel plate and the floors are of two layers of wood armored on the underside with steel plates. Ventilation is obtained by means of 12 suction ventilators along the roof.

The interior is divided into four compartments, the one at the forward end being the engine room, behind which is a small baggage compartment, then a smoking compartment and a main passenger compartment taking up a large part of the body. A small observation room is provided at the rear end and toilet facilities are included. The interior of the car, with the exception of the engine room, is finished in selected Mexican mahogany. The seats are upholstered in leather and individual electric lights, one at each seat, furnish the artificial light. Exceptionally good natural lighting is obtained by the very large double windows. There is no wood used in the engine compartment.



EIGHT CYLINDER GASOLINE ENGINE AND 90 K.W. GENERATOR.

The gasoline engine, which develops 100 brake horse-power at 550 r. p. m., is direct connected to a 90-k.w. direct current gen-

erator, which furnishes current at variable voltage. This current is fed to the motors through the medium of a control system, by means of which the voltage of the generator may be governed according to the requirements. Two motors are provided, each being rated at 60 h.p.

Engine.—The gasoline engine has eight cylinders, each of which is 8 in. in diameter, and has a stroke of 7 in. The cylinders are placed four on each side at 90 degs. to each other or an angle of 45 degs. with the vertical. Each cylinder casting is of very soft fine grained iron and is self-contained, including the water jacket. There is one admission and one exhaust valve for each cylinder, which are so arranged as to permit the inspection of both valves by the removal of 2 nuts. The connecting rods are chrome nickel steel and the crank shaft is a forging of 40-point carbon steel. It is a four-throw crank, having an angle of 180 degs., all of the crank pins being in the same plane. The two center cranks are on the same side of the shaft and the two outside cranks are set at 180 degs. with these. Two connecting rods, one from each cylinder, are connected to each crank pin. This arrangement of cranks and cylinders gives a most satisfactory system for balancing purposes, as well as a practically constant torque. Each cylinder is fastened to the engine base by six bolts, the base being made of one casting of Parsons' manganese bronze. The crank casing, which is made oil tight, is of aluminum.

All of the valves are actuated from one cam shaft, which is entirely enclosed in a circular tunnel running the entire length of the engine base and formed in the main casting.

There are two carburetters of the float feed type and the ignition is high tension, a separate coil being provided for each cylinder. The cooling system operates on the thermo-syphon principle, the radiator being situated on the roof of the car. The total cooling surface amounts to about 1,300 sq. ft. The water jackets are connected to the radiator by means of pipes running vertically from the engine and the circuit is completed by means of other pipes leading from the radiator to the cylinder jackets. This forms the most simple system of cooling arrangement possible as it entirely eliminates the necessity of using pumps or cooling fans.

Considerable difficulty has been experienced in starting gasoline engines of this size and the same principle that proved so satisfactory in starting the engine in the former car has been used in this case. This consists of a special breech block mechanism fitted into the top of one of the cylinders, which fires a black powder cartridge and gives an impulse for starting the engine. This piece of mechanism is illustrated in one of the photographs and can be put into any cylinder desired, being left in place while the engine is being operated.

The gasoline is stored in a large steel tank of 90 gallons capacity, suspended beneath the floor of the car. The supply is raised by means of a diaphragm pump to a small auxiliary tank in the cab, being filtered in transit. It is fed to the carburetter from this tank by gravity. Forced lubrication is used, there being a nest of pumps operated from the main shaft. All of the oil used for lubricating purposes flows to the crank case from which it can be drained and filtered.

Generator.—The generator is a G. E. 90-k.w. eight-pole separately excited unit, which has been specially designed with the view of obtaining the lightest possible machine for the output and at the same time keeping the temperature rise within a reasonable figure. It is provided with commutating poles, which in connection with the potential type of control gives a great flexibility. The advantage of this arrangement is readily appreciated when it is considered that at starting the field excitation is weak and large currents are required to give the necessary starting torque to the motors. The normal voltage of the generator is 250 volts, at which time the current is 360 amperes, but at starting a current of 800 amperes can be secured at a corresponding decrease in voltage. It would be impossible to commutate so large a current in a machine of so great a k.w. capacity per pound without the use of commutating poles. The total weight of the generator, including the exciter, is only 2,740 lbs. while a standard machine of this output weighs 8,800 lbs. While the temperature rise is higher and the efficiency lower in this generator than in standard apparatus these conditions have been fully considered in the design. The efficiency, however, proves to be 88 per cent., or only 3 per cent. lower than the standard machine.

The exciter is a 3-k.w. 70-volt shunt wound generator with its armature mounted directly on the armature shaft of the main generator and its field yoke supported by the bearing brackets, enabling it to fit under the back end of the generator armature windings.

Control System.—The speed of the motors on the trucks is governed by potential control. Since the generator is separately excited the voltage delivered can be varied by means of rheostats connected in series with the exciting current. The master controller, which is arranged to give seven steps with the motors connected in series and eight steps with them connected in parallel, has four handles, three of which are mounted one above the other on concentric shafts. The function of the top handle is to advance and retard the ignition of the engine; the second handle controls the throttle of the engine and the third handle controls the rheostat in the exciting current and hence the voltage of the generator and the speed of the motors and also gives the change in motor connections from series to parallel. The fourth handle operates the reversing switch.

A storage battery is provided for supplying the lighting circuits and normally floats upon the exciting circuit. Its charging and discharging is controlled by means of a reverse current relay which permits the lights being supplied directly from the exciting circuit or the storage battery, according to the voltage of the circuit.

BREECH BLOCK MECHANISM FOR FIRING BLACK POWDER CARTRIDGE.

The car is heated by passing part of the exhaust gases through pipes located in the car body. The brakes are of the straight air type, the compressor being direct connected to the engine.

The trucks are of the swing bolster type with 36-in. wheels, there being one motor mounted on each truck. These were designed and constructed by the American Locomotive Company.

The car body, which was built by the Wason Manufacturing Co., of Springfield, Mass., has the following general dimensions:

Length over all	50 ft.
Length of engine room	9 ft. 6 in.
Length of passenger compartment	26 ft. 5 in.
Width	8 ft. 8 in.
Height over all	12 ft. 10½ in.
Seating capacity	44

SIGNAL TESTS.—A series of 197 surprise tests of signals on the Lehigh Valley Railroad has just been completed and it is reported that every one was obeyed exactly. The entire main line of this road is fully equipped with automatic signals.

CO-EFFICIENTS OF FRICTION BETWEEN WHEELS AND RAILS.*

By George L. Fowler.

The resistance of a wheel to slipping on the rail depends upon two causes frequently confused, but which are to be considered separately. These are friction and abrasion.

Frictional resistance is due to the roughness of the two surfaces in contact, and may be compared to the lifting of the weight to be moved over the successive inequalities of the surface on which it rests. Abrasion, on the other hand, involves the removal or cutting away of the particles of the masses in contact. The slipping of a wheel, such as would produce a flat spot, involves both frictional resistance and abrasion. If there were no slipping of the wheel on the rail there would be no wear, provided the rolling action did not produce sufficient pressure on any one point to crush the metal or cause it to flow. But there is always more or less slip even on a straight line.

There are two kinds of slipping to which car wheels may be subjected. One is the skidding action due to the locking of the wheels by the brake-shoes. The other form occurs when the driving wheels of electric motor cars, for instance, are turned faster than the corresponding rate of motion of the car and the whole periphery of the wheel slides over the rail. In order to determine whether the resistances to these two kinds of slipping were the same, certain experiments were made.

The apparatus was designed to produce, as nearly as possible, the actual conditions of track work.

Two pieces of steel rails of 75 lbs. section, one of which had been worn smooth in service; the other, a piece of new rail, together with a section of a steel wheel and a section of a cast-iron wheel, with the treads of both smooth and free from imperfections, were used for the tests. The testing machines were made by Tinius Olsen & Company, one with a capacity of 100,000 lbs. and the other a capacity of 50,000 lbs.

The apparatus is shown in the accompanying illustrations for the skidding movement. The wheel section was set on the rail and loaded by the 100,000 lbs. capacity machine. It was then slipped over the rail by a pull on the connection rod reaching to the other machine which measured the amount of the pull required to slip the wheel on the rail.

In loading the wheel, the pressure was applied through a plate resting on two rollers. In this way the friction, except that between the wheel and the rail, was reduced to practically nothing.

For the spinning motion, the bearing plate above the rollers was made convex and the bottom plate resting on the top of the wheel was made concave; both surfaces being concentric with the tread of the wheel. A pull on the wheel, therefore, caused it to roll under the bearing plate as though it were revolving on its own center. The arrangement of this is clearly shown in the diagram.

The force required to move the wheel on the rail was weighed by a bell crank with a knife edge bearing, resting on a heavy casting attached to the bed plate of the small testing machine. The vertical arm was attached to the pull rod and the end of the horizontal arm had a bearing on a wedge or knife edge that was forced down by the platen of the machine.

The wheel section was placed in position on the rail and weighted with a predetermined load. Pressure was then applied to the wedge on the small machine. This pressure was transferred through the bell crank as a pull on the connecting rod. When slipping occurred, the event was marked instantly by the drop of the beam of the small machine. The movement of the wheel over the rail usually amounted to about 1-32 in. As the object of the investigation was to determine the friction at rest no attempt was made to measure the pull after the first slip occurred. This was markedly less than that required to start the movement from a state of rest.

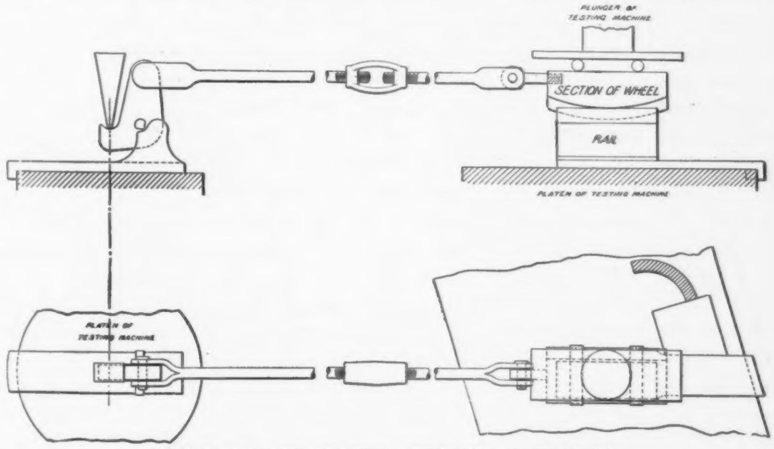
* Reprinted by special permission from "The Car Wheel," copyrighted by the Schoen Steel Wheel Company.

Separate tests were made with steel and cast-iron wheels on the old and new rails, for both the skidding and spinning motions. In loading the wheels, the weights were increased by regular increments of 2,000 lbs. up to 30,000 lbs. Three tests were made with each loading and for each condition of wheel movement. The average of the three tests in each case is given in the accompanying table.

There was so little difference in the pull required to slip the wheels on the old and new rails that an average of the results obtained is given as the resistance to spinning and skidding of the two wheels on a steel rail.

Load on Wheel in Lbs.	Kind of Motion.			
	Spinning.		Skidding.	
	Steel Wheel.	Cast Iron Wheel.	Steel Wheel.	Cast Iron Wheel.
2,000 lbs.........	.259	.243	.285	.267
4,000 "	.240	.215	.254	.259
6,000 "	.234	.208	.245	.254
8,000 "	.228	.206	.246	.242
10,000 "	,215	.204	,238	.233
12,000 "	.212	.205	.237	.223
14,000 "	.207	.199	.233	.226
16,000 "	.204	.196	.232	.219
18,000 "	.204	.198	.231	.219
20,000 "	.201	.194	.236	.220
22,000 "	.205	.191	.238	.223
24,000 "	.204	.192	.235	.224
26,000 "	.205	.189	.232	.223
28,000 "	.203	.186	.236	.217
30,000 "	.203	.183	.234	.214

The table shows that the resistance to spinning of the steel wheel is somewhat greater than that of the cast-iron wheel, a fact



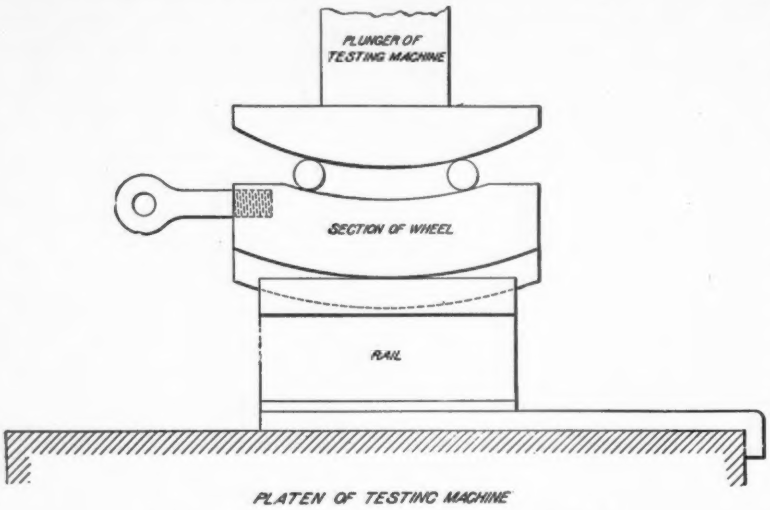
APPARATUS FOR TESTING SKIDDING RESISTANCE.

which is brought out quite forcibly by the coefficients of friction, in which the coefficient of the steel wheel is invariably higher than that of the cast-iron.

It also appears from this table, that the coefficient of friction of the steel wheel decreases as the load is increased, up to a pressure of about 15,000 lbs., after which it is practically constant. The coefficient of friction of the cast-iron wheel decreases rather rapidly, like that of the steel wheel, up to a load of 15,000 lbs., after which it falls away slowly, though a tendency to decrease with the increase of load is manifest.

As regards skidding, the values of the coefficients of the two wheels bear the same relation to each other as they do for spinning. The coefficient of resistance is greater for the steel wheel than for the cast-iron wheel; and there is the same falling off in the value of the coefficient as the load is increased up to about 15,000 lbs., after which that of the steel wheel is nearly constant, while that of the cast-iron wheel continues to fall away slowly. It would be difficult to explain these phenomena without the data obtained in the investigations previously described, made to determine the area of contact between the wheel and the rail, and the relative rate of abrasion of the steel and cast-iron wheels on the emery wheel. The results of those investigations also serve to explain why the coefficient for a skidding wheel is higher than the coefficient for a wheel that is spinning.

In the case of the cast-iron wheel, it was shown in the preceding chapter that the imposition of a heavy load caused a breaking down of the metal in the rail at a certain point, while no such failure occurred with the steel wheel under the same load. The cast-iron wheel being rigid, inelastic and incompressible on the tread, was forced down into the metal of the rail, causing the rail to do all of the yielding needed to produce the area of contact obtained; with the result that it was soon compressed beyond its elastic limit and given a permanent set. The steel wheel yielded as well as the rail, thus relieving the rail of a part of its compression and increasing the area of contact. This behavior of the two wheels explains, in part, the results obtained in these tests. In addition, it must be remembered that the normal coefficient of friction is greater between steel and steel, than it is between cast-iron and steel.



APPARATUS FOR TESTING SPINNING RESISTANCE.

When the cast-iron wheel is loaded on the rail, it indents the rail in proportion to the pressure applied, without being distorted itself. If, then, it is turned, as by a motor, it simply revolves in the concave depression in the rail, without undergoing any deformation itself and with no resistance other than that of overcoming the friction between the surfaces of the wheel and rail. The steel wheel, on the other hand, is itself compressed, as well as the rail, so that when it is turned a continuous progressive compression of the tread is set up, equal to the amount of the original compression. Hence, the resistance to turning will be equal to the frictional resistance plus that set up by this compression.

It was shown that the cast-iron wheel was cut away much more rapidly under the emery wheel than were the steel tires and wheels. In the tests for skidding, the loads were successively applied without readjusting the wheel on the rail, with the result that the steel wheel was skidded about $1\frac{1}{4}$ in. and the cast-iron wheel about 1 in. This was done under loads increasing from 2,000 lbs. up to 30,000 lbs. Under this treatment, the steel wheel developed a slid-flat spot about 9-16 in. long, and the cast-iron wheel a spot about 7-8 in. long. In both cases the rail was spotted and the metal was rolled up in folds, indicating the direction of the motion of the wheel. The piece of rail used with the steel wheel was spotted for a distance of about $1\frac{3}{4}$ in., while the piece used with the cast-iron wheel was spotted for a length of about $1\frac{1}{2}$ in. This abrasion of the cast-iron wheel probably accounts for the lower resistance to skidding as compared with the steel wheel. For the same weight and for the same distance of skidding, the amount of metal abraded from the cast-iron wheel was in almost exactly the same ratio to that removed from the steel wheel, as is shown in the diagram of abrasion tests.

It will be remembered that, for the lower wheel loads, the investigation of contact areas showed that there was comparatively little difference between the areas obtained with cast-iron wheels and with steel wheels, and that it was inferred that the total compression of the metal was approximately the same in both cases. Under these circumstances it would be expected that, if the power required to distort the metal of a steel rail and tire were the same, the resistance to skidding of the steel wheel and the cast-iron wheel would also be the same. But, owing to the more rapid abrasion of the cast-iron wheel, as soon as it begins to skid it wears, and, by thus increasing the area of contact, it lessens the depression of the rail, decreases the amount of metal to be distorted, lowers the resistance to the motion, and makes the coefficient of friction of skidding less on the cast-iron wheel than on the steel wheel.

This depression of the rail, due to the imposition of the wheel load, accounts for the higher coefficient of friction obtained with a skidding wheel than with a spinning wheel. With a wheel spinning, there is no continuous deformation of the metal of the rail to be affected. In skidding, there is a depression of the rail to be carried forward like a wave, which naturally raises the resistance and makes the coefficient greater than where slipping over one spot alone takes place.

While it is not safe to draw rigid conclusions from the limited amount of data obtained, it does appear that inasmuch as the steel wheel offers greater resistance to spinning it is better adapted for use as the driving wheel of an electric car than the cast-iron wheel; and further, its higher coefficient of friction renders it less liable to skidding.

This matter of wheels skidding, with the consequent development of flat spots on the tread, was considered of enough importance to warrant further investigation.

It has been noted by many other investigators that steel wheels do not flatten as readily as cast-iron wheels. By some this is attributed to the fact that small flat spots, once formed on the tread of a steel wheel may be rolled out, whereas they have a tendency to grow larger on cast-iron wheels. The abrasion and skidding tests which have been made seem to show, however, that it is the lower resistance to grinding of the cast-iron wheel that accounts for the more rapid development of these flat spots.

To briefly recapitulate, these tests showed that the rate of grinding of the first $\frac{1}{8}$ in. below the tread was about 4.64 times as fast in the cast-iron wheel as in the Schoen steel wheel. For the second $\frac{1}{8}$ in. the ratio became 6.37, and for the third $\frac{1}{8}$ in., 15.93, showing the rapid decrease of wearing resistance of the cast-iron wheel below the surface. In the skidding tests in the laboratory, the effects were confined to the metal close to the surface, and it was found that, with the same amount of skidding, the amount of metal removed was about 5.12 times as great on the cast-iron wheel as on the steel wheel. A further check on these figures was afterwards obtained by taking the time required to remove approximately the same amount of material from the treads of cast-iron and steel wheels in a wheel grinding machine. It was found that it took from four to five times as long to grind down the steel wheels as it did to grind the cast-iron wheels. In all of the foregoing investigations, the metal of the wheel under test was kept cool, either by a stream of water or by doing the work so slowly that natural radiation counteracted the tendency to heat and the temperature of the metal was not raised above 100 deg. Fahr.

For the purpose of ascertaining whether the results of these investigations were comparable with the results obtained in actual railroad service, when the wheels were locked and skidded under a car, series of tests were made by skidding the wheels under a loaded car.

Through the courtesy of the New York, Ontario & Western a piece of track and a suitable box car were supplied for the tests. One pair of wheels and axle were removed from under the car, and replaced by an axle on which a Schoen steel wheel and a new cast-iron wheel had been pressed. These wheels were $33\frac{3}{4}$ in. and 33 in. in diameter, respectively. This pair of wheels were placed at the end of the car, and was fitted with two brake-beams, so that twice the usual brake-shoe pressure could be applied on the wheels. By this means, the wheels could be held in a fixed position throughout a run. But it was more difficult to hold the wheels at low speed than at high speed.

The car was loaded until the weight on the pair of wheels to be tested was exactly 24,000 lbs. The car was then hauled back and forth over a piece of track 1,850 ft. long. The brake was set and the wheels skidded for the whole distance. The car was hauled at two speeds, namely, 3 and 12 miles an hour.

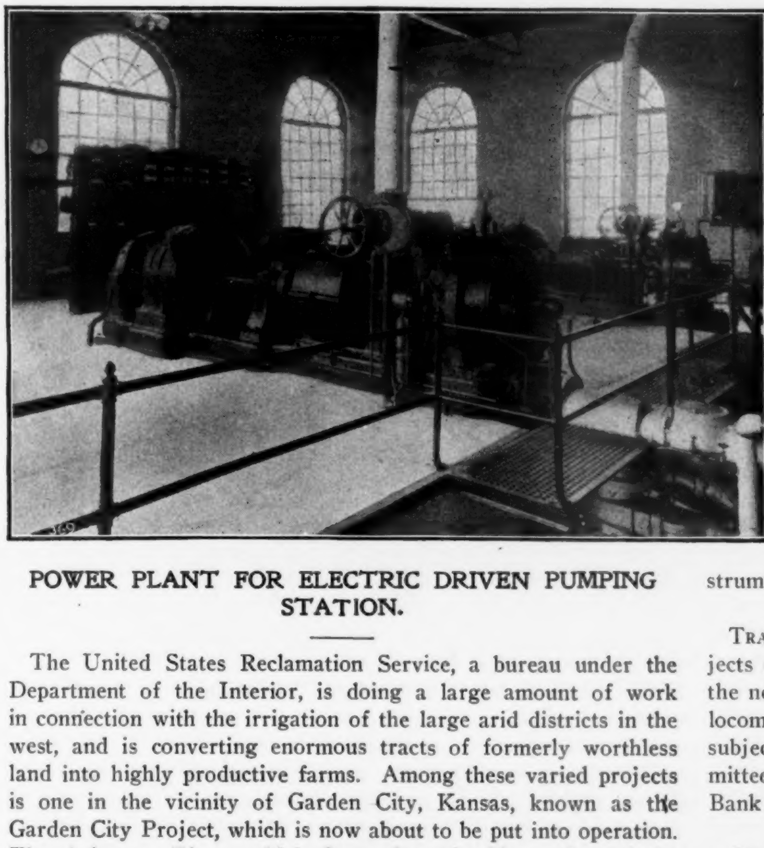
When the car was hauled at a speed of 3 miles an hour, flat spots were made on the steel wheel in area about .30 in., while the spots formed on the cast-iron wheel were in area .80 in. These areas correspond to diameters of about 5/8 in. and 1 in., respectively, though the spots on the cast-iron wheel were elongated to about 1 1/8 in., which indicated somewhat more metal removed. The volume of metal abraded from the cast-iron wheel was about 5 3/4 times greater than that from the steel wheel.

While the movement was slow the wheels remained cool. But when the speed was increased to 12 miles an hour, heating took place and the cutting was more rapid on the steel wheel.

For the first 1,850 ft. run the areas of the flat spots produced at a speed of 12 miles an hour averaged 8.125 sq. in. on the steel wheel and 4.445 sq. in. on the cast-iron wheel. The estimated amount of metal worn away was 4.63 times as much with the steel wheel as with the cast-iron wheel.

When the skidding was continued the rate of wear increased very rapidly with the cast-iron wheel, while there was little increase with the steel wheel. At the end of the run of 3,700 ft., the area of the flat spot on the steel wheel was 8.43 sq. in., an increase of .305 sq. in., while the area of the spot on the cast-iron wheel was 5.72 sq. in., an increase of 1.275 sq. in. From this it appears that the cast-iron wheel wore away more rapidly than the steel wheel after the hard surface metal had been broken through.

The indications are that in skidding a short distance at low speed a cast-iron wheel is more apt to develop a flat spot than is a steel wheel. On the other hand, if the skidding continues for some distance at a high speed, the wheel becomes heated and then the steel wheel is the first to yield, unless the surface chill of the cast-iron wheel has already been worn through.



POWER PLANT FOR ELECTRIC DRIVEN PUMPING STATION.

The United States Reclamation Service, a bureau under the Department of the Interior, is doing a large amount of work in connection with the irrigation of the large arid districts in the west, and is converting enormous tracts of formerly worthless land into highly productive farms. Among these varied projects is one in the vicinity of Garden City, Kansas, known as the Garden City Project, which is now about to be put into operation. The Arkansas River, which flows through this section of the country, carries, in the wet season, a large body of water, but during the dry season its bed is practically dry. There is, however, in all seasons a considerable body of water flowing a short distance below the surface of the ground and this project consists of a central electric generating station and twenty-three separate electric-driven pumping stations located along the line of flow of the underground water, which makes it available for irrigation purposes during the dry weather.

The area affected is a strip of land, about 10,000 acres, extending for about twenty miles northeast of the river. It consists of a canal running through the strip from which the various irrigation ditches are led. This canal, which is known as the "farmer's ditch," is connected to the Arkansas River, and during the period of high water is fed from that source, a flood gate being provided to control the supply. During the dry season, however, the canal is fed by the pumping stations.

The power plant which furnishes the electric current for operating all of these stations is of the most efficient and modern type and a very high economy of operation has been secured. In the boiler room there are two 200 h.p. Sterling boilers generating steam at 160 lbs. pressure with 120 degrees superheat. Draft is obtained by a steel stack 150 ft. high. In the engine room there are two turbo generators of 225 k.w. capacity, each generating three-phase 60-cycle current at 6600 volts. The exciter is direct connected to the shaft of each of the generators. The turbines are fitted with an automatic system for filtering and supplying their own lubricating oil. The current is controlled by oil switches located in the basement, which are mechanically operated from a switchboard of five panels placed in the engine room.

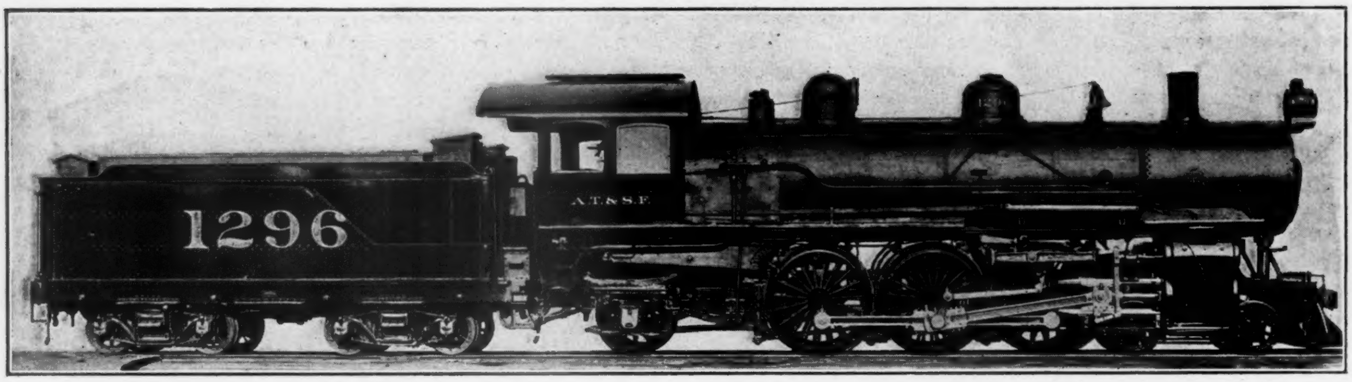
The power plant is a brick and steel structure located adjacent to the line of the Santa Fé Railroad near Deerfield, Kansas. The coal supply is brought in by the railroad, a siding being provided for storing the cars. The current is carried on overhead lines to the different pumping stations.

The D'Oiler Engineering Company, of Philadelphia, were the engineers and contractors for the entire power generating plant.

TESTING PLANT FOR ELECTRIC CARS.—There has been installed in the electrical laboratories of the Worcester Polytechnic Institute a testing plant for heavy electric street and interurban cars. The plant, in general, consists of four pairs of supporting wheels mounted in pedestals, which are adjustable along the base and can be arranged to suit any car. The shafts of these wheels are extended for the purpose of attaching fly wheels, whose weights are adjustable, which serve the purpose of imitating the starting inertia of the car on test. The train grade and curve resistance, which is usually obtained by absorption brakes, is in this case obtained by connecting electric generators to each shaft. The four generators are of the same type and size and have their fields connected in series. The exciting current is obtained from a direct current machine with adjustable field rheostat. The current in the field may thus be varied, as desired, by changing the voltage of the exciting generator. The armatures of the four generators are connected in parallel to the load resistance. The generators are connected to the shafts by a pinion and gear, the usual suspension bearings being used. Although a traction dynamometer for registering the drawbar pull has not yet been installed, it is expected that eventually such an instrument will be put into place.

TRAVELING ENGINEERS' ASSOCIATION.—The committee on subjects desires all members to submit subjects for consideration at the next annual meeting, which will be of general interest to the locomotive department and of benefit to the association. Any subject submitted will be given careful consideration by the committee, of which Mr. W. G. Wallace, 1600 Commercial National Bank Building, Chicago, is the chairman.

ELECTRICAL NIGHT AT THE NEW YORK RAILROAD CLUB.—The March meeting of the New York Railroad Club will be given up to the annual electrical night, at which short papers by a number of authorities on electrification of steam railways will be read.



PACIFIC TYPE LOCOMOTIVE WITH BALDWIN SUPERHEATER—A. T. & S. F. RY.

LOCOMOTIVES WITH LOW BOILER PRESSURE AND SMOKEBOX SUPERHEATERS.

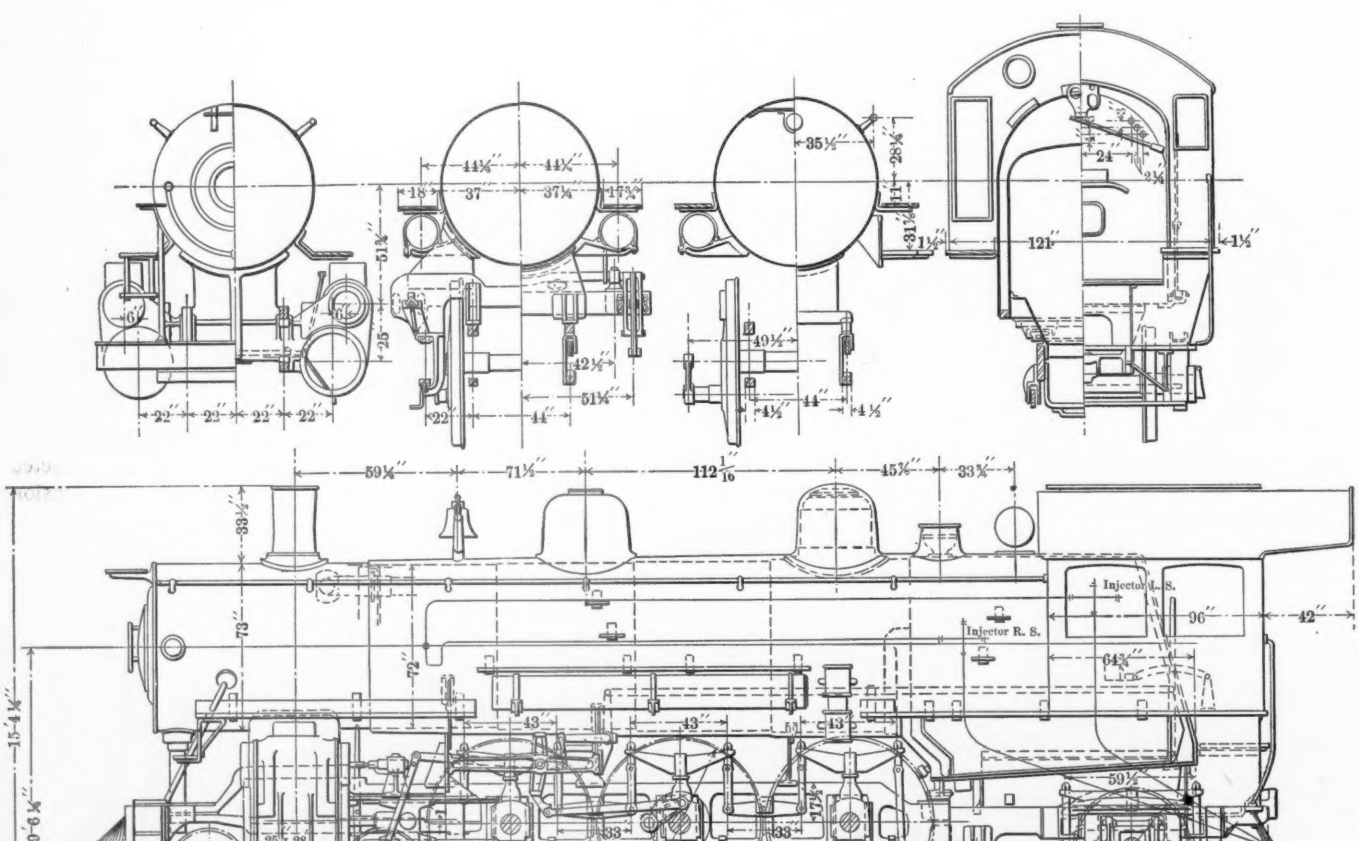
ATCHISON, TOPEKA & SANTA FE RAILWAY.

The Baldwin Locomotive Works has recently completed an order of 49 locomotives for the Atchison, Topeka & Santa Fe Ry., of which seven are of the Pacific type and 42 of the consolidation type. Ten of the latter are equipped for burning coal and all of the remainder are arranged for burning oil. These locomotives carry a boiler pressure of but 160 lbs. and are fitted with very large simple cylinders, so as to take advantage of the full adhesive weight with this low boiler pressure. The difficulty from condensation, which would be greatly increased because of the large increase in the area of the walls in these cylinders, has been reduced by the installation of smokebox superheaters in all of the locomotives. The superheaters are of the Baldwin type and are not intended or expected to deliver highly superheated steam but simply to give sufficient superheat to overcome the excessive condensation.

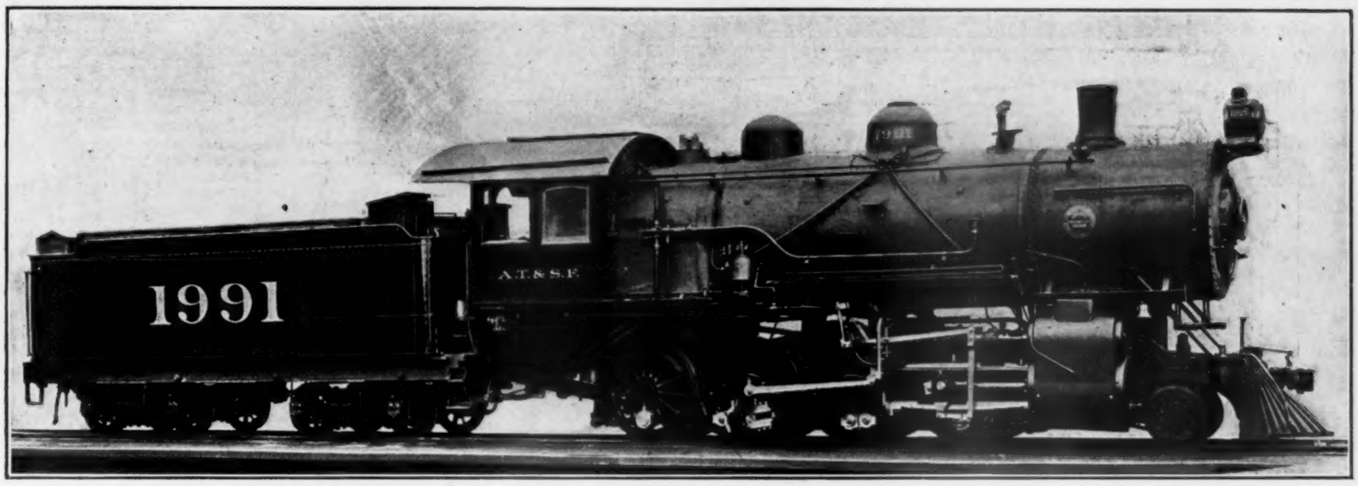
The Santa Fe has for some time been operating a ten-coupled locomotive with a superheater of this design and using a low boiler pressure with results which have been so satisfactory as to lead to the same arrangement on this large order of both freight and passenger engines. The principle advantage gained by this arrangement is the reduction in boiler troubles and ease of maintaining full pressure, especially in bad water districts where great difficulty has been found in keeping boilers tight.

Pacific Type Locomotives.—The seven passenger locomotives have 25x28 in. cylinders; 73 in. drivers and give a tractive effort of 32,600 lbs. They weigh nearly 233,000 lbs., of which 140,400 lbs. is on drivers, giving an average weight per driving axle of 46,800 lbs. This gives a factor of adhesion of 4.33 and a ratio of total weight to tractive effort of 7.12.

The boiler is of the straight type, 72 in. in diameter at the front ring. It contains 273-2-¼ in. tubes 20 ft. long, which give a heating surface of 3,202 sq. ft., or practically the same amount that will be found on a similar weight locomotive carrying 200 lbs. boiler pressure. The ratios of heating surface and grate area to cylinder volume, however, are naturally considerably



ELEVATIONS AND SECTIONS OF PACIFIC TYPE LOCOMOTIVE—A. T. & S. F. RY.



CONSOLIDATION LOCOMOTIVE WITH BALDWIN SUPERHEATER—A. T. & S. F. RY.

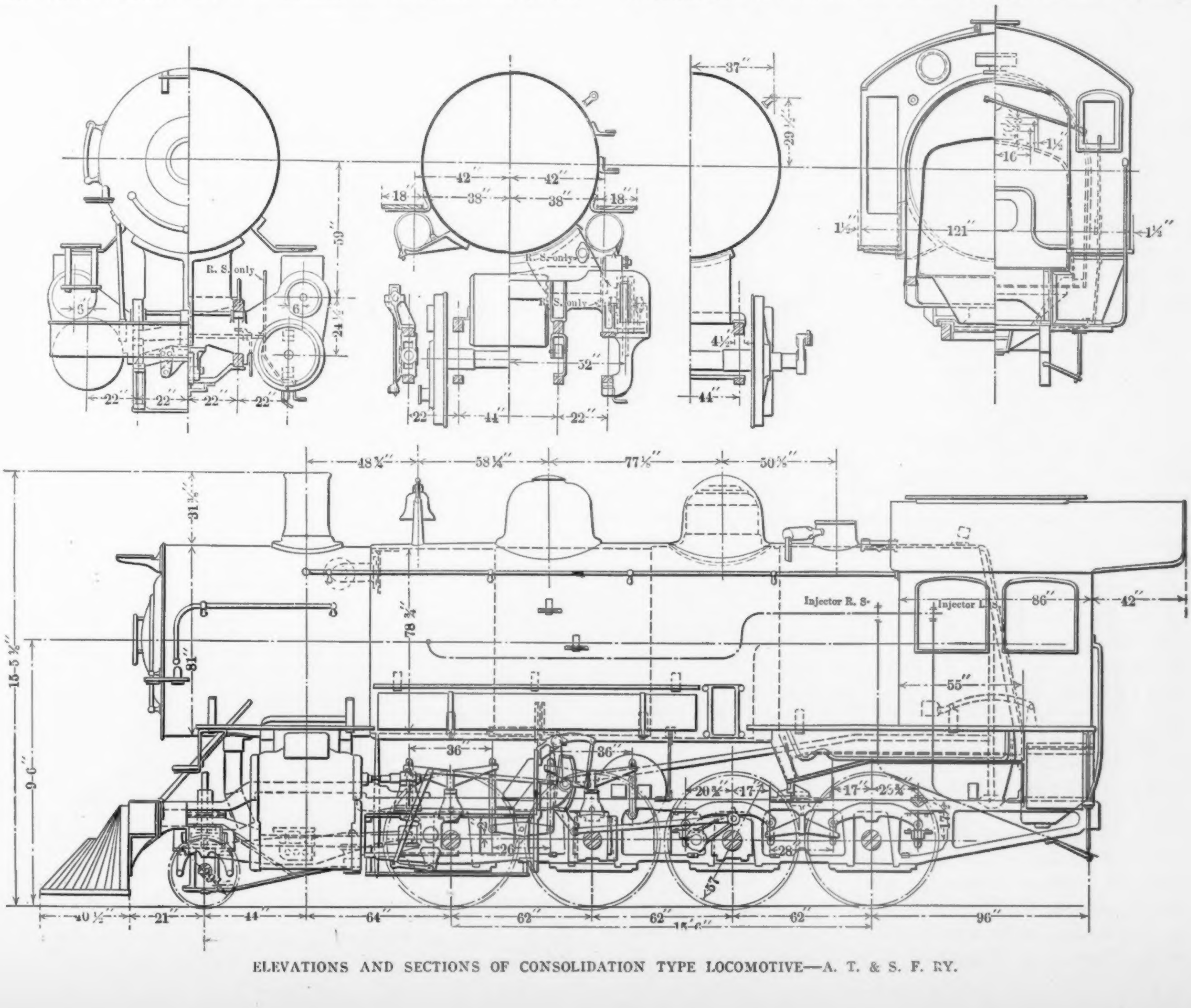
smaller than would be the case with the engine having higher pressure and smaller cylinders. The boiler barrel is built up of four rings having "diamond" butt jointed seams on the top center line.

The superheater is the same in general design as the one shown on page 89 of the March, 1907, issue of this journal, but differs from it in having the saturated steam enter the superheater at the front end and work backward, the final outlet being at the end nearest the front tube sheet, or at the point where the hottest gases are found. It has a heating surface of 709 sq. ft., giving 1 sq. ft. of superheating surface to about 4.5 sq. ft. of boiler heating surface.

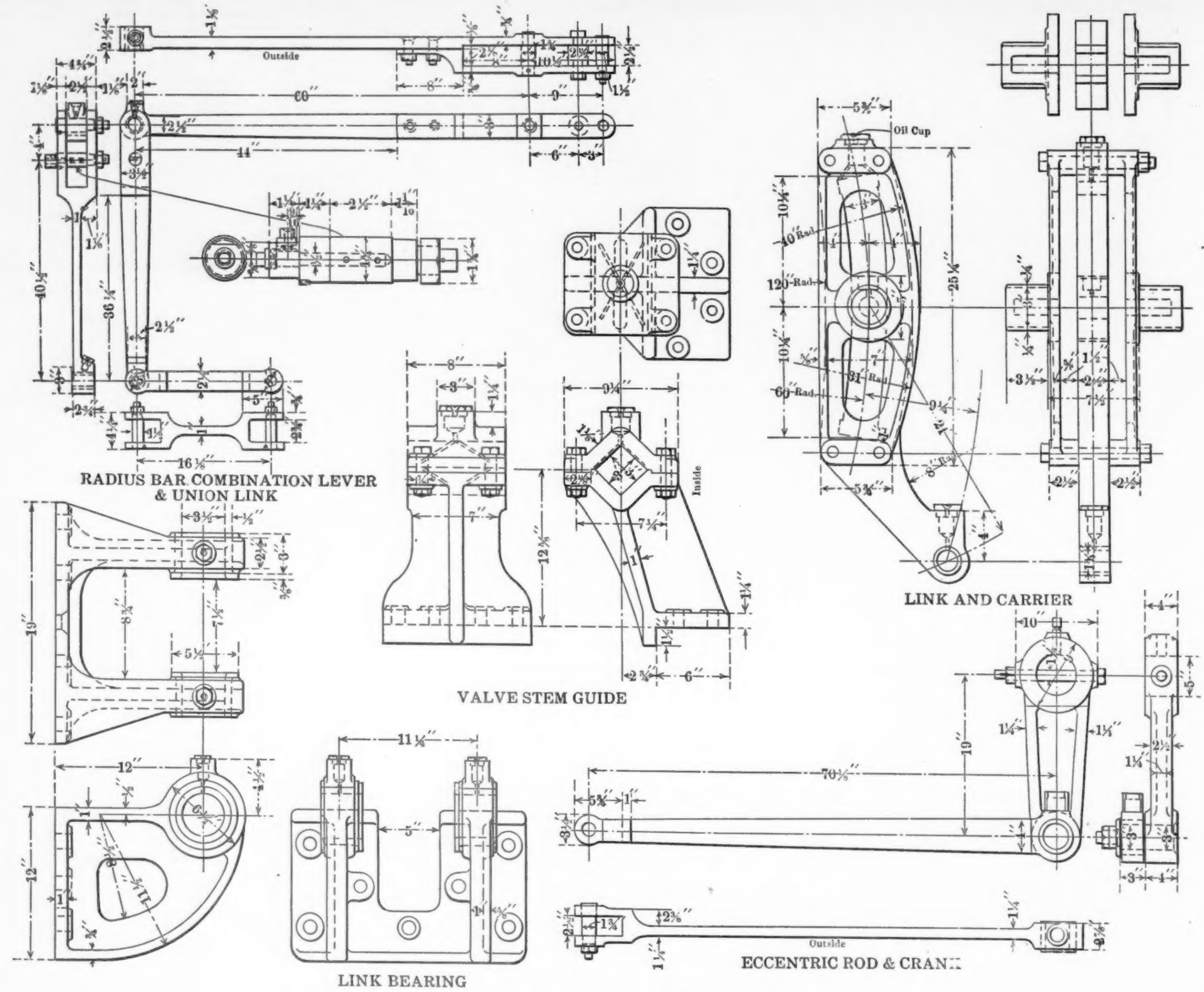
The cylinders are designed for the Walschaert valve gear and have valve chambers set 6 in. outside of the center line of the cylinders, so as to place the valve motion in practically one vertical plane. The arrangement of the valve gear is clearly shown in the general elevation and follows the most recent practice in design for Pacific type locomotives by having the link hung from cast steel supports located outside of the drivers and parallel to the engine frame, being carried by the guide yoke at the front and a suitable cross bearer at the rear. Outside of the link bearers, the details of this gear are practically the same as those for the consolidation locomotive, which are illustrated herewith and will be mentioned later.

The front truck is of the swing bolster type with cast steel saddle and 3-point suspension links. The rear truck is of the Rushton pattern with outside journals.

Consolidation Locomotives.—These locomotives have 24 x 32



ELEVATIONS AND SECTIONS OF CONSOLIDATION TYPE LOCOMOTIVE—A. T. & S. F. RY.



DETAILS OF WALSCHAERT VALVE GEAR ON PACIFIC TYPE LOCOMOTIVE.

in. simple cylinders, 57 in. driving wheels and a tractive effort of 43,970 lbs. The boiler is also of the straight top design; measures 78¾ in. outside diameter at the front end. It contains 355 2-in. tubes, 15 ft. long, giving a total heating surface of 2,930 sq. ft. The boiler ratios and ratios of boiler to weights are about the average for this type of locomotive. The superheater is of the same design as used in the Pacific type engines and has 600 sq. ft. of heating surface, which is a ratio of 1 to 4.87 with the boiler heating surface.

The Walschaert valve gear design as applied to these locomotives is an excellent example of probably the simplest arrangement of this type of gear. It is all located in practically one vertical plane, and there is but one reversing shaft, and as few separate parts as can conveniently be used to fulfil the requirements. The link bearing and reverse shaft bearing are bolted to the wrought iron guide yoke which is given a good depth outside of the frames and is secured to them by a very large cast steel knee having ample bearing on the frame and for the full depth of the guide yoke. The top guides are also secured to the yoke by a cast steel knee. The link bearing, which has been designed with a view of obtaining the greatest rigidity with the least weight, is shown in the illustration, as is also the link itself, which is of wrought iron in one piece and is secured between two cast steel carriers having trunnions resting in the brass bushings of the link bearings.

The valve stem is keyed to a case hardened square sectioned extension, which rests in a cast steel guide secured to the top guide bar. This extension has ample bearing in its support, being set with the flat faces at an angle of 45 degs. It connects at the rear to the combination lever, the details of which are shown in the illustration, through a specially designed pin, also illustrated. This pin is arranged with a central passage and outlets in the center of the bearing, through which the lubricant can reach the bearing surfaces.

The eccentric crank is of cast steel in one piece being fitted over a 5 in. diameter extension on the end of the crank pin and secured in place by a bolt passing through it and the main pin. The construction and arrangements of the other parts of the gear are clearly shown in the detailed illustrations.

The general dimensions, weights, and ratios of both types of locomotives are given in the following table:

GENERAL DATA.		
Type	Pacific	Consolidation
Gauge	4 ft, 8½ ins.	4 ft. 8½ in.
Service	Passenger	Freight
Fuel	Oil	Oil
Tractive effort	32,600 lbs.	43,970 lbs.
Weight in working order	232,750 lbs.	212,400 lbs.
Weight on drivers	140,400 lbs.	183,200 lbs.
Weight on leading truck	54,950 lbs.	29,200 lbs.
Weight on trailing truck	37,400 lbs.	
Wt. of engine and ten. in work. order	395,000 lbs.	375,000 lbs.
Wheel base, driving	12 ft. 8 in.	15 ft. 6 in.
Wheel base, total	34 ft. 5 in.	24 ft. 6 in.
Wheel base, engine and tender	65 ft.	58 ft. 3 in.
RATIOS.		
Weight on drivers ÷ tractive effort	4.33	4.17
Total weight ÷ tractive effort	7.12	4.75
Trac. ef. × diam. driv. ÷ heat. surf.	700.00	855.00
Total heating surface ÷ grate area	68.50	62.00
Fireb'x heat. surf. ÷ t'l heat. surf., %	5.60	5.35
Weight on drivers ÷ total heat. surf.	41.50	62.50
Total weight ÷ total heating surf.	68.50	72.50
Volume both cylinders, cu. ft.	16.00	16.80
Total heating surf. ÷ vol. cylinders	212.00	174.50
Grate area ÷ vol. cylinders	3.10	2.82
CYLINDERS.		
Kind	Simple	Simple
Diameter and stroke	25 × 28 in.	24 × 32 in.
VALVES.		
Kind	Piston	Piston
Diameter	13 in.	13 in.
Greatest travel	6¼ in.	

Outside lap	1⅛ in.	
Inside clearance	⅛ in.	
Lead, constant	¼ in.	
Valve gear	Walsch.	Walsch.
WHEELS.		
Driving, diameter over tires	73 in.	57 in.
Driving, thickness of tires	3½ in.	3½ in.
Driv. jour., main diam. and length	10 × 12 in.	10 × 12 in.
Driv. jour., others, diam. and length	9 × 12 in.	9 × 12 in.
Engine truck wheels, diameter	34¼ in.	29¼ in.
Engine truck, journals	6 × 10 in.	6½ × 10½ in.
Trailing truck wheels diameter	50 in.	
Trailing truck, journals	8 × 14 in.	
BOILER.		
Style	Straight	Straight
Working pressure	160 lbs.	160 lbs.
Outside diameter of first ring	72 in.	78¾ in.
Firebox, length and width	108 × 66 in.	95½ × 71¼ in.
Firebox, plates, thickness	⅜ & 9/16 in.	⅜ & ½ in.
Firebox, water space	F-4½, S-5, B-4 in.	F-4½, S & B-4 in.
Tubes, number and outside diam	273—2¼ in.	355—2 in.
Tubes, length	20 ft.	15 ft.
Heating surface, tubes	3,202 sq. ft.	2,773 sq. ft.
Heating surface, firebox	190 sq. ft.	157 sq. ft.
Heating surface, total	3,392 sq. ft.	2,930 sq. ft.
Superheater heating surface	759 sq. ft.	600 sq. ft.
Grate area	49.5 sq. ft.	47.4 sq. ft.
Smokestack, height above rail	184¼ in.	185⅞ in.
Centre of boiler above rail	114¼ in.	114 in.

TENDER (BOTH TYPES)

Tank	Waterbottom
Frame	12 in. channels
Wheels, diameter	34¼ in.
Journals, diameter and length	5½ × 10 in.
Water capacity	8,500 gals.
Oil capacity	3,300 gals.

VANADIUM IN CAST IRON.*

For a number of years admirable reports on alloys research have come from Europe, and among them one would occasionally see mention of vanadium and its remarkable effect on steel. The practical steel-maker, however, knowing the high price of this rare metal could only regret that vanadium had no commercial application.

Since the discovery recently of enormous deposits of vanadium, more particularly those in Colorado, matters have assumed a different shape. Prof. Hildebrand, of the U. S. Geological Survey, first located a deposit of vanadi-ferous sandstone in that state, and this is now being worked extensively, and the ferro-alloy made right in this country. The supply of vanadium is practically unlimited.

The properties of vanadium steel are as follows: The elastic limit is increased without an impairment of the ductility of the steel—that is, an exceedingly strong steel is obtained, with its softness still remaining. Coupled with these most valuable properties is another, and that is the extreme resistance to deterioration when the metal is subjected to severe and continued strains in service. Vanadium steel is nonfatiguing, and, therefore, an ideal railroad and rolling mill metal. It is but natural that attention should be drawn to the use of vanadium in the foundry. The very first casting which might be benefited is the car wheel. Next would come the various kinds of rolls, then alkali pots, pump parts, etc.—wherever strains are heavy and oft repeated, either direct tension and compression alternately and in cases where castings are subjected to shock or great variations in temperature.

In order to learn something of the effects of vanadium on cast iron a series of tests was conducted, using melted scrapped car wheels for white iron and a good machinery pig iron for a variety of gray iron. A ferrovanadium carrying high carbon was selected because it melted at a lower temperature and would also be cheaper for the foundryman. Varying proportions were added to the ladle full of molten metal, first in lump form, and, as this did not give satisfaction with the small quantities of iron used at a time, the alloy was powdered before using.

Inasmuch as vanadium, besides being a great strengthener, is also a powerful deoxidizing agent, and the increase in strength obtained by its use might be attributed to the purification of the iron only, a further series of tests was included in which the ladle was first treated with 80 per cent. ferromanganese in sufficient quantity to add 0.5 per cent. of manganese, and then the ferrovanadium. In order to obtain some light on the deoxidizing power of vanadium a set of tests was also made with burnt metal, the results of which are given in the tables below.

* From a paper delivered before the American Foundrymen's Association by Dr. Richard Moldenke, Secretary of the Association.

The test bars were of the regulation kind, as prescribed by the American Society for Testing Materials—namely 1¼ in. round, cast on end, and in dried molds. The test bars, dumped when cold, were only brushed and then broken transversely on a 5000-lb. Riehle testing machine. As there were quite a lot of tests, and many of the bars varied slightly in diameter from the standard, the breaking weights were all recalculated from the modulus of rupture back to the standard 1¼-in. test bar. This, while not correct in its strictest sense, for cast iron is not homogeneous and does not follow the rules applicable to steel, nevertheless gives a fair comparison of the general effects of the alloy addition.

TABLE I.

Burnt Iron, Gray (Burnt grate bars, stove iron, etc.)

Average of 5 bars—no vanadium added:	
Broke at	1,310 lbs.
Deflection	.09 in.
Modulus of rupture	25,500 lbs.
Average of 3 bars—.05 per cent. vanadium added:	
Broke at	2,220 lbs.
Deflection	.1 in.
Modulus of rupture	43,380 lbs.

TABLE II.

Burnt Iron. White.

Average of 3 bars—no vanadium added:	
Broke at	1,440 lbs.
Deflection	.05 in.
Modulus of rupture	28,170 lbs.
Average of 12 bars—.50 manganese and .05 vanadium added:	
Broke at	1,910 lbs.
Deflection	.055 in.
Modulus of rupture	37,400 lbs.

TABLE III.

Machinery Iron. Gray (melted pig—no scrap).

Average of 5 bars—no vanadium added:	
Broke at	1,980 lbs.
Deflection	.105 in.
Modulus of rupture	38,680 lbs.
Average of 5 bars—.05 vanadium added:	
Broke at	2,070 lbs.
Deflection	.105 in.
Modulus of rupture	40,410 lbs.
Average of 19 bars—.10 vanadium added:	
Broke at	2,200 lbs.
Deflection	.115 in.
Modulus of rupture	42,600 lbs.
Average of 4 bars—.15 vanadium added:	
Broke at	2,740 lbs.
Deflection	.13 in.
Modulus of rupture	53,750 lbs.
Average of 3 bars—.5 manganese added, no vanadium:	
Broke at	1,970 lbs.
Deflection	.1 in.
Modulus of rupture	38,410 lbs.
Average of 5 bars—.05 ground vanadium added:	
Broke at	1,980 lbs.
Deflection	.1 in.
Modulus of rupture	38,700 lbs.
Average of 4 bars—.5 Mn. and .05 ground vanadium added:	
Broke at	2,130 lbs.
Deflection	.1 in.
Modulus of rupture	41,780 lbs.
Average of 5 bars—.10 ground vanadium added:	
Broke at	2,372 lbs.
Deflection	.09 in.
Modulus of rupture	46,320 lbs.
Average of 3 bars—.5 Mn. and .10 ground vanadium added:	
Broke at	2,530 lbs.
Deflection	.12 in.
Modulus of rupture	49,590 lbs.
Average of 5 bars—.15 ground vanadium added:	
Broke at	2,360 lbs.
Deflection	.1 in.
Modulus of rupture	46,070 lbs.

TABLE IV.

Remelted Car Wheels. White—no pig iron.

Average of 5 bars—no vanadium:	
Broke at	1,470 lbs.
Deflection	.05 in.
Modulus of rupture	28,100 lbs.
Average of 5 bars—.05 lump vanadium added:	
Broke at	2,190 lbs.
Deflection	.05 in.
Modulus of rupture	41,570 lbs.
Average of 7 bars—.10 lump vanadium added:	
Broke at	2,050 lbs.
Deflection	.05 in.
Modulus of rupture	39,750 lbs.
Average of 8 bars—.15 lump vanadium added:	
Broke at	2,264 lbs.
Deflection	.06 in.
Modulus of rupture	44,480 lbs.
Average of 4 bars—.50 Mn. and no vanadium:	
Broke at	2,790 lbs.
Deflection	.07 in.
Modulus of rupture	54,570 lbs.
Average of 6 bars—.05 ground vanadium:	
Broke at	3,020 lbs.
Deflection	.06 in.
Modulus of rupture	59,030 lbs.
Average of 6 bars—.50 Mn. and .05 ground vanadium added:	
Broke at	2,970 lbs.
Deflection	.09 in.
Modulus of rupture	58,040 lbs.
Average of 3 bars—.10 ground vanadium:	
Broke at	2,800 lbs.
Deflection	.055 in.
Modulus of rupture	54,890 lbs.

Average of 4 bars—.50 Mn. and .10 ground vanadium added:

Broke at	3,030 lbs.
Deflection	.09 in.
Modulus of rupture	59,220 lbs.

Average of 6 bars—.15 ground vanadium:

Broke at	2,950 lbs.
Deflection	.07 in.
Modulus of rupture	59,230 lbs.

Average of 6 bars—.50 Mn. and .15 ground vanadium added:

Broke at	3,920 lbs.
Deflection	.095 in.
Modulus of rupture	76,650 lbs.

The analyses were for the most part made on bars in which the powdered alloy was used, as these tests were most satisfactory. All tests, however, are given as they seem to confirm the belief that the addition to the strength of the metal is a well-founded one. The vanadium alloy used contained

Vanadium	14.67
Carbon	6.36
Silicon	0.18

While the vanadium content is comparatively low, this is a very good alloy for foundry purposes, as cast iron is already high in carbon, and the silicon is too small to cut an appreciable figure in the results. While the attempt was made to get as nearly 0.5, 0.10 and 0.15 vanadium into the ladles of metal as possible, the analyses show that for the bars selected (as nearly the average for strength as possible) as much as two or three times actually remained after casting. This is due first to the impossibility of accurately weighing out in the small space of time available to prevent undue cooling of the metal, most of the time dealing with less metal in the ladle than expected or arranged for. Then, with the small quantities tried, the chances for irregular distribution were very great. A foundry with 5 or 10 ton ladles would give a better opportunity. Finally there is the uncertainty of how much or little vanadium is oxidized. The very best results with both manganese and vanadium show very little of the latter remaining.

The results, however, are sufficient to strongly recommend the new alloy to the consideration of foundrymen. If but a part of the resistance of deterioration found by adding vanadium to steel should be proven by service trials to exist in cast iron, then on the score of safety to human life alone, the metal belongs in every car wheel. A still better method would be to use a more powerful deoxidizer than manganese and add the vanadium on top of it.

The results shown in the tables speak for themselves, and the averages tallied off for each table show a remarkable progression of values. To increase the breaking strength of a test bar from 2000 up to 2500 for gray iron, and 1500 up to 3900 for white iron is sufficient to warrant further investigation on the part of every foundryman who has special problems in strength to master, and this part of the investigations is therefore given to the foundry public at this time, rather than to wait for the further tests still on the programme. It is expected to continue the investigations on vanadium in cast iron further, making provision to keep the ladle with melted iron heated up for a fairly long period, so that better mixing of the alloy may result, and hence more accurate results can be obtained.

Elkhart Roundhouse Burns.—A large section of both roundhouses, together with the accompanying repair shop and storeroom of the Lake Shore & Michigan Southern Railway, at Elkhart, Ind., were destroyed by fire on the morning of January 9. The fire started by the ignition and explosion of a barrel of front end paint located in the store-room, and spread with such incredible rapidity that in spite of the splendid work of the shop and city fire departments, it destroyed all of the shop building, with the exception of the oil house, as well as eight stalls in each of the roundhouses, before being brought under control. On practically all of these stalls were locomotives, and since one of the first effects of the fire was to destroy the electrical connection to the turn-tables, it was impossible to remove even such of these locomotives as had steam pressure, and they were all badly burned and will require a complete overhauling. Work of rebuilding the structures was started as soon as the ruins had cooled.

HOLLOW STAYBOLTS.

By John Hickey.*

Having been troubled with broken staybolts on several mountain engines, due to variation of pressure followed by extremes of temperature several times a day, the writer had some hollow staybolts placed on surfaces giving the most trouble from broken bolts. As the solid staybolts and those having drilled telltales were removed, they were replaced by hollow ones. After about a year of this practice it was noticed that the staybolt work at the short run terminals was very materially reduced. Prior to this the life of the solid staybolt with telltale drilling was between five and nine months, depending on location in staying, while after this time, a little over a year, there was no record of a single hollow bolt being broken, although located mostly in what was considered the breaking zone. Longer periods of experience with the hollow bolt developed equally good results, its endurance being remarkable under the severe conditions existing.

The self-warning principle of the hollow staybolt is highly appreciated by those directly in touch with the power generator. Eliminating the hammer tests, together with the feeling that no dangerous number can be broken without compelling attention, is regarded as a very satisfactory condition. It is well known that the strength of wrought iron decreases after reaching 350 degrees F. Moderately high firebox temperature causes a solid staybolt to reach the depreciative heat, this being one of the causes which shortens its life. With the hollow staybolts in service a streamlet of cool air passes through each bolt to the furnace, thus holding the metal at a lower temperature, furnishing both strength and endurance that cannot be obtained with the use of the highest possible grade of iron in the solid staybolt. The greater endurance of the inner ends of the hollow bolts, as compared with solid ones, is very noticeable. This is due to the in-rushing air through the hollow bolts cooling the ends of the bolts and reducing the waste of the iron due to the high heat of the fire.

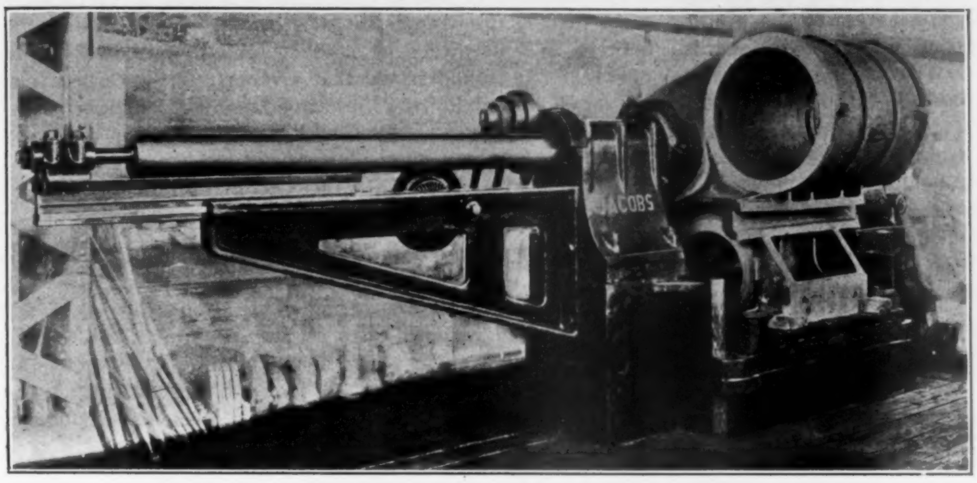
It is said that a few have closed the center holes at the inner ends of the hollow staybolts with a couple of blows of the hammer, claiming the entrance of too much cold air. This practice, the writer is certain, should be discouraged. In order to obtain full benefits from the hollow bolts, the air should be permitted to pass through the ⅛-in. hole to the fire. This will hold the staybolt to lower temperature, add to its strength and flexibility, cause greater endurance to the inner ends, and while aiding combustion will add noticeably to the efficiency of the furnace. It will further afford a double advantage for the detection of breakages should any occur, as the annular hole passes entirely through the bolt and failure at any point will immediately make itself known.

Hollow staybolts with both ends open will never stop up, as the current of air passing through them always keeps the holes free from sediment. Furthermore, the hollow bolt saves material and time in application and renewals, and also prevents injury to sheets in making renewals, as the operator has a central hole for his drill to follow.

* Salt Lake City.

The Next World's Fair.—Work on the grounds and buildings of the Alaska-Yukon-Pacific Exposition, which will be held at Seattle, Washington, June 1 to October 15, 1909, is well under way and the management has announced that beyond doubt the work of building, grading, etc., will be completed on the opening day. This fair differs from previous fairs in many ways, the first of which is that the National Government has not been asked for any money to carry on the work.

Issue of Patent Four Weeks from Allowance.—As most inventors know, it has hitherto been the practice of the United States Patent Office to issue patents on inventions three weeks after the date of allowance on payment of the final government fee. The Commissioner of Patents has given instructions that hereafter the period between the date of allowance and the issue of the patent shall be four weeks.—*Scientific American.*



SINGLE BAR BORING MACHINE, A. T. & S. F. RY.

SINGLE BAR BORING MACHINE FOR MULTIPLE CYLINDERS.

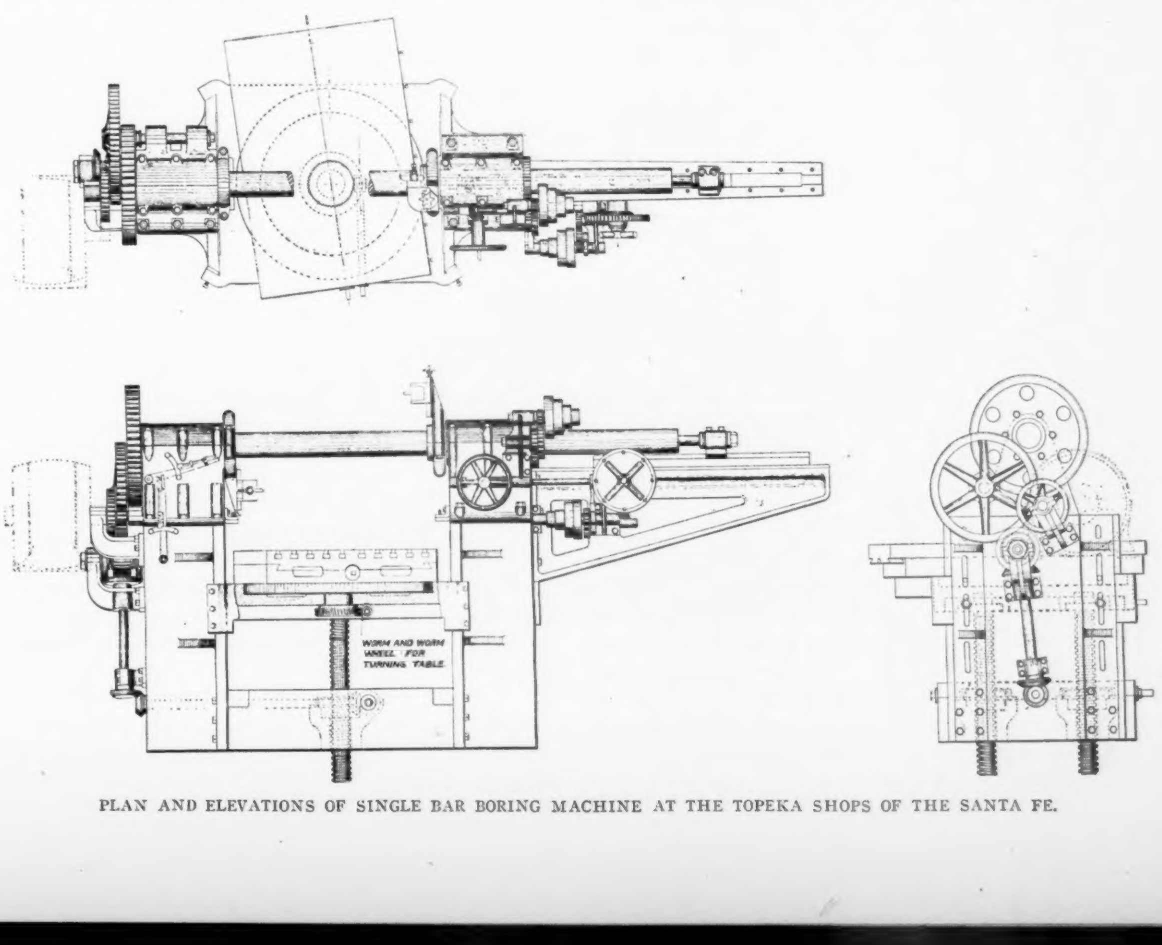
By E. J. McKernan.*

The usual locomotive cylinder boring machine consists of a horizontal spindle and table permitting of either no adjustment at all or only lateral adjustment. With these machines of the old design much time is consumed in properly setting the cylinder so that the boring bar will strike the true center, and furthermore, high speeds and rapid cutting cannot be obtained. These disadvantages are, of course, magnified when cylinder castings having two or more cylindrical chambers are to be bored and faced, because the work has to be set twice, and the cylinders and valve chambers (where piston valves are used) must be truly parallel with each other. These machines, designed when simple slide valve cylinders of not more than 18 in. or 20 in. in diameter were the prevailing type on locomotives, were adapted for use with the slow speed carbon steel which was the most efficient material for making cutting tools at that time. The mechanism was simple, but the driving and feed gears were weak cast iron affairs which drove the tool along at an unprofitably slow speed. Later, as the art of cutting materials was on a more scientific basis, and tool steels of greater cutting capacity and speed were introduced in shop practice, attempts to work these new cutting tools to their proper limits in boring machines of this class, would result in stripping the gears, or other injury to the machine.

With the later developments in high speed cutting tools of great capacity, and in locomotive construction, with engines having piston valves and often compound cylinders on the Vauclain principle or on the four cylinder balanced compound principle, a machine capable of the most effective service under the latter conditions becomes a shop necessity. In order to meet this demand, one manufacturer produced a three-spindle machine which would require but one setting of the work and which would insure the parallel boring of all cylinders and chambers. While this type of machine possesses many advantages for certain classes of work, still the single bar machine has been found superior for general railroad practice. A comparison of the two types shows that the single bar has less gearing and is the simpler machine, and is consequently much easier maintained. On account of the smaller number of parts, the single bar machine is the most economical to drive, and the power required can be obtained from a small motor. Where there are some advantages in boring three chambers at once it has been found in practice that the chatter in one tool is transmitted to the other tools causing a rough finish in all bores. This, of course, is entirely obviated in the single bar machine. From experience in the ordinary railroad shop it has been found that the single bar machine is best suited to all-around locomotive work. It is economical in operation, in power consumed and in adjustments, and, owing to the less machinery involved, it is the most economical to buy.

Recently there have been built several heavy and solid single bar boring machines with the boring bars capable of the heaviest

* Tool Expert, A. T. & S. F. R'y System.



PLAN AND ELEVATIONS OF SINGLE BAR BORING MACHINE AT THE TOPEKA SHOPS OF THE SANTA FE.

strains, and of such a design as to insure working the cutting tools to the very highest capacity. The accurate setting of the work, especially in connection with the multiple cylinders, is brought about by the application of a table having both lateral and vertical adjustment, and these machines produce very excellent work. But the examples of them thus far constructed are heavy ponderous affairs, costing a great deal for the weight of metal in them alone, and they do not have the universally wide range for accommodating all classes of locomotive cylinder boring that should be a requisite in modern machines for this purpose. Their first cost is high, and the best results are not always obtained from them, not to speak of the relative large amount of shop room required.

At the Topeka shops of the Santa Fé Railway there has been built a cylinder boring mill which answers all the requirements in regard to the boring of cylinders for all classes of compound engines. This machine is also adapted to bore cylinders on engines which have one cylinder or chamber at an angle to the others. All cylinders or chambers may be bored at one clamping of the cylinder, by the mere raising or lowering of the table. This table has an elevating movement of 37 in.; also has a cross travel of 35 in. The table which has the cross travel movement has also a swiveling motion, by which a range of 15 degrees incline may be had.

This new boring mill, as can be seen in the illustration, is direct motor driven. The table is raised or lowered by power connection with the main motor through beveled gears and clutches, handled from the operator's side of the machine. All the mechanism is of the latest design and is strong and durable, all gears being made from good gray iron and all bushings of phosphor bronze. The boring bar is 7 in. in diameter and is made from open hearth steel. It is fed through the cylinder by means of a spur gear and rack which makes it very rigid in operation and gives a very smooth bore.

One of the facing heads on the machine is made so that it will move along on the bar and is driven by means of a 1-in. key and set screw, and will pull any kind of a cut that is put on the machine. The facing heads are fed by means of a star feed attachment. The screws that elevate the table are made from soft steel and are 5½ in. in diameter and are ¾ pitch, the screws set at right angles to the boring bar, making everything rigid. The total weight is about 15 tons, and the machine takes up floor space of 223 sq. ft., having an extreme length of 21 ft. and an overall range in width of 14 ft.

This machine is capable of boring a three-chamber compound cylinder in 15 hours or in a year of 3,000 working hours you can bore 200 three-chamber compound cylinders. You can also bore a simple cylinder in three hours or 1,000 in a year of 3,000 working hours.

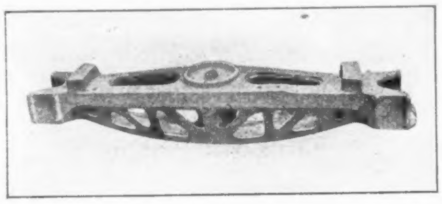
On the old style boring mill it has taken from 26 to 28 hours to bore a three-chamber compound cylinder. Thus, by the use of this modern boring mill, 11 hours can be saved on each three-chamber compound cylinder, where it used to take from 8 to 10 hours to bore a simple cylinder. One of these cylinders can now be bored in three hours on this machine; thus making a saving of 5 hours on each simple cylinder bored, or over $1,500 a year in operator's wages alone, in addition to increasing the machine capacity from only 375 cylinders per year, to 1,000 simple cylinders, giving an output of 625 more cylinders per year. Where only 115 three-chamber compound cylinders could be handled with the old style boring mill, the new machine will bore 200 cylinders, thus increasing the output of compound cylinders about 77 per cent.

If a machine which bores only one chamber of a locomotive cylinder casting at one time is to compete successfully with one which can bore three chambers simultaneously, it must not only bore rapidly, but it must be so constructed so that only one setting will be required to bring the chambers into position to bore. This arrangement has been attained in this new machine, insuring that after a cylinder has been lined up and clamped on the table any of the chambers may be brought exactly into position for boring and making it impossible to bore two chambers out of parallel unless desired.

The machine of this design which has been in operation for some time at the Topeka shops is giving first-class satisfaction, both in its convenience in handling, and in the lower production cost. It is understood that arrangements have been made for the Tool and Railway Specialty Manufacturing Company of Atchison, Kansas, to handle machines of this type on the market.

CAST STEEL TRUCK BOLSTER.

A satisfactory truck bolster requires great strength in the horizontal, as well as in the vertical, plane, combined with a certain amount of elasticity, and should also be as light in weight as possible. The accompanying illustration shows a bolster which has been designed with all of these conditions, together with a number of minor requirements, kept clearly in view. It is made of cast steel in one piece, in the form of a truss, the tension member being a solid thin plate of cast steel, the compression member being considerably wider, and of greater section at the edges, is cut out on either side of the center plate to secure lightness.



The sides forming the vertical and diagonal members are inclined and provide simply sufficient metal to properly take care of the stresses, the useless material being cut out, as is shown in the illustration. The inclination of the sides permits them to assist somewhat in carrying the horizontal as well as the vertical stresses, and also allows the use of a deeper truss by giving a tension member of a width which will give a clearance between the flanges of the commonly inverted channel iron or angles forming the truck cross tie. At the same time a compression member of even greater width and strength than usual is obtained. The side bearings, center plate and dead lever fulcrum are cast integral with the bolster, doing away with all riveting.

These bolsters are made to suit any dimensions or to carry any desired weight. Trials on a testing machine have shown that the bolster for a 60,000-lb load will show no permanent set at 100,000 lbs., and has an ultimate breaking load of 200,000 lbs. The 100,000-lb. bolster shows no set at 150,000, and breaks between 325,000 and 400,000 lbs.

This bolster is designed and is being manufactured and sold by the Gould Coupler Company, 341 Fifth avenue, New York.

PERSONALS.

J. F. Marshall has been appointed general store keeper of the Wabash Railroad at Canton, Ohio.

H. Sayles, one of the pioneer railroad men of Buffalo, N. Y., died recently at his home in that city.

The office of general master mechanic of the International & Great Northern R. R. has been abolished.

James McDonough has been appointed general foreman of the Trinity & Brazos Valley Ry. at Galveston, Texas.

J. T. Lendrum has been appointed master mechanic of the Oklahoma division of the Santa Fe, with office at Arkansas City, Kan.

C. H. Kessler has been appointed mechanical engineer of the El Paso & Southwestern R. R., with headquarters at El Paso, Texas.

G. W. Taylor, master mechanic of the Oklahoma division of the Santa Fe, has been transferred to the Middle division at Newton, Kan.

E. F. Fay, master mechanic of the Union Pacific R. R. at Denver, Colo., has been transferred to Cheyenne, Wyo., as superintendent of shops.

J. A. Doarnberger has been appointed master boiler maker of the Norfolk & Western Ry., with jurisdiction of the boiler work of the whole system.

J. G. McLaren has been appointed master mechanic of the Chicago, Rock Island & El Paso Ry., with office at Dalhart, Tex., in place of J. McDonough.

J. L. Sydnor, formerly bonus supervisor of the Coast Lines of the Santa Fe, has been transferred to Topeka as bonus supervisor of the Eastern Grand Division.

J. A. Turtle, assistant superintendent of motive power of the Union Pacific R. R., has been transferred to Denver, Colo., succeeding E. F. Fay as master mechanic.

J. F. Whiteford, general roundhouse inspector of the Santa Fe, has been appointed bonus supervisor of the Coast Lines, with headquarters at San Bernardino, Cal.

Michael Flanagan has been appointed master mechanic of the Montana division of the Great Northern Ry. at Havre, Mont., in place of K. Froburg, transferred.

G. J. DeVilbiss, superintendent of motive power of the Toledo & Ohio Central Ry., has had his jurisdiction extended to include the Marietta, Columbus & Cleveland R. R.

The office of J. S. Chambers, superintendent of motive power of the Atlantic Coast Line, has been changed from Wilmington, N. C., to South Rocky Mount, N. C.

A. Dinan, master mechanic of the Middle division of the Santa Fe, has been transferred to the Missouri division, with office at Fort Madison, Ia., in place of J. H. McGoff, promoted.

T. S. Reilly, associate editor of the *Railway and Engineering Review*, at Chicago, has resigned, to become superintendent of the mechanical department of the Canton & Hankow Railway at Canton, China.

C. F. Harding has been appointed professor of the school of electrical engineering at Purdue University. Prof. Harding comes from Cornell, where he has held the position of associate professor of electrical engineering.

Charles E. Fuller, until recently superintendent of motive power of the Chicago & Alton R. R., has been appointed assistant superintendent of motive power and machinery of the Union Pacific R. R. at Omaha, Neb.

J. P. McCuen, superintendent of motive power of the Cincinnati, New Orleans & Texas Pacific Ry., has resigned that position, effective on March 1, when he will take the rest to which he is entitled after long years of service. Mr. McCuen entered the employ of the Queen & Crescent Route as road foreman on March 1, 1882.

The master mechanics of the Atlanta, Birmingham, Knoxville and Selma divisions of the Southern Railway, have been transferred as follows: John F. Sheahan, Atlanta, Ga., transferred to Knoxville, Tenn.; J. B. Michael, Knoxville, Tenn., transferred to Selma, Ala.; G. Akans, Selma, Ala., transferred to Birmingham, Ala., and N. N. Boyden, Birmingham, Ala., transferred to Atlanta, Ga. It is reported that these changes are in accordance with a new ruling on that road which requires the transfer of all master mechanics every two years.

The New York, New Haven & Hartford R. R. has transferred master mechanics as a result of the rearrangement of divisions. The appointments and headquarters now are as follows: New York division, J. M. Collins at Harlem River; the Shore Line, P. C. Zang, at New Haven; the Providence, G. A. Moriarity, at Providence; the Boston, J. Hocking, at South Boston; Old Colony, D. R. Killinger, at Taunton; the Midland, J. B. Gannon, at East Hartford; the Western, H. C. Oviatt, at New Haven. J. McCabe, heretofore engine foreman at the Harlem River terminal, has been appointed general road foreman of engines, with headquarters at New Haven.

NOTES

REFINED IRON & STEEL CO.—This company announces that it has been compelled to put in a new 9 in. mill to take care of its increasing business. Its mills are located at Pittsburg, Pa.

MONTREAL LOCOMOTIVE WORKS.—The Secretary of State of Canada issued Supplementary Letters Patent on Feb. 5 changing the corporate name of "The Locomotive & Machine Company of Montreal, Limited," to that of "Montreal Locomotive Works, Limited."

RUMOR DENIED.—The Charles G. Smith Co., 603 Park Building, Pittsburg, Pa., announces that the rumor, which has been in circulation, to the effect that since its connection with the Pittsburg Emery Wheel Company it has discontinued the machine tool business, is not true.

ROUNDHOUSE BURNS.—The roundhouse and machine shops of the Central New England Railroad, at Fishkill Landing, N. Y., were destroyed by fire on February 13. In addition to the buildings there was a locomotive and a number of machine tools destroyed. The loss was about $100,000.

AMERICAN TOOL WORKS CO.—At the annual meeting of the stockholders and directors of the above company held on January 21, the following officers were elected: President, Franklin Alter; Vice-President and General Manager, J. P. Doane; Secretary, Robert S. Alter; Treasurer, Henry Luers.

MONARCH EMERY & CORUNDUM WHEEL CO.—Mr. Chas. A. Bacmeister has been appointed western representative of the above company, with headquarters at Chicago. Mr. Bacmeister has had an extensive experience in the grinding wheel field and his friends will no doubt be pleased to hear of his new connection.

FROST RAILWAY SUPPLY COMPANY.—At a meeting of the directors of the above company, held in Detroit on Tuesday, February 11, the following officers were elected: Mr. Harry W. Frost, president; Mr. George A. Cooper, vice-president; Mr. Frederick H. Holt, treasurer; Mr. James Whittemore, secretary, and Mr. H. C. Smith, assistant secretary.

THE DEARBORN DRUG & CHEMICAL WORKS.—Mr. Robert F. Carr and several of his associates in the above company, have purchased the holdings of the estate of the late Wm. H. Edgar and at a recent meeting of the stockholders the following officers were elected: Mr. R. F. Carr, president and general manager; George R. Carr and Grant W. Spear, vice-presidents; Wm. B. McVicker, vice-president and general manager; J. D. Purcell, assistant general manager; W. A. Converse, assistant secretary and chemical director; R. R. Browning, assistant treasurer and A. E. Carpenter, superintendent.

G. DROUVE CO.—At the annual meeting of the directors of the above company, held on Feb. 3, Mr. G. Drouve was elected president and treasurer, and Mr. William V. Dee secretary. Mr. Dee, who recently resigned from the staff of the *Railway Age*, has also been appointed general sales manager. This company manufactures the "anti-pluvius" sky-light, of which 125,000 sq. ft. have been installed at the Hoboken terminal of the D. L. & W. Railroad, and the Lovell window operating device, which is in use in the shops of many of the railroads, as well as the Drouve ventilators, drying stoves, etc. It will exhibit its sky-light and window operating device at the annual convention of the American Railway Engineering and Maintenance of Way Association, to be held at Chicago March 17 to 19.

PASSENGER CAR LIGHTING, CANADIAN PACIFIC RAILWQY.—The Safety Car Heating and Lighting Company has just completed the installation of 8,000 of its latest single mantel lamps in cars on the Canadian Pacific Railway. This type of mantel is capable of giving 99.5 candle power with a gas consumption of 2.12 cu. ft. per hour, which costs about one cent. These mantels have more than met the expectations of the company in regard to the length of service, as they have averaged a life of more than four months in actual srvice, while the expectation did not exceed a life of three months. In connection with this new equipment the Pintsch Compressing Company has completed the installation of plants at Vancouver, Moose Jaw and Winnipeg, Canada, and has arranged for charging facilities on the Canadian Pacific Railway at Montreal and Toronto.

CATALOGS

IN WRITING FOR THESE PLEASE MENTION THIS JOURNAL.

LOCK NUTS.—Wm. Howard Co., Philadelphia Bourse, is issuing a leaflet illustrating and describing the Blanton lock nut. This nut is made in sizes to fit bolts from ¼ to 4 in. in diameter.

New Prices.—The Burke Machinery Company, Cleveland, O., is issuing a sheet of new prices of the machines manufactured by it. These include milling machines, drill presses, cut-off saws, oil forges, etc.

Vises.—The Hollands Mfg. Co., Erie, Pa., is issuing catalog A2, illustrating and describing a large variety of vises, plumbers' tools and natural gas burners. A table of sizes, capacities and prices is included with each tool.

Cast Steel Bolsters.—The Gould Coupler Company, 341 Fifth Ae., New York, is issuing part catalog No. 4 illustrating and describing the "Crown" cast steel body and truck bolsters, which are designed to give a maximum strength with a minimum weight.

Valves for High Pressure.—Jenkins Brothers, 71 John St., New York, is issuing a supplement to its 1907 catalog, which supersedes pages 70 and 71 therein and gives illustration and description, as well as details of sizes and prices, of extra heavy gate valves for 150 and 250 lbs, steam pressure.

Air Compressors.—The Bury Compressor Co., Erie, Pa., is issuing two new bulletins. No. 30 contains illustrations and full description of duplex and compound air compressors either steam or belt driven in all practical sizes and capacities. No. 32 treats in a similar manner the center crank design of air compressors and vacuum pumps.

Railroad Signaling.—The Union Pacific Railroad is issuing a very attractive pamphlet containing a large number of three color views showing the automatic signals installed on that system. These pictures are accompanied by a description of the apparatus and an account of its working. A brief history of railway signaling is also given.

Instructions for Using Thermit.—The Goldschmidt Thermit Co., 90 West St., New York, is issuing a book giving full instructions for the use of thermit in repair work. This includes a list of the tools and appliances required for different classes of work and detailed explanation of the proper method of preparing the work and making the weld.

Steam and Water Specialties.—The Golden Anderson Valve Specialty Company, Fulton Building, Pittsburg, Pa., is issuing a leaflet which illustrates and describes pressure reducing valves, non-return valves, tilting steam traps, float valves, altitude valves, clean seat valves, gauge cocks and water gauges. These valves are made for serving all pressures and capacities.

Foundry Information.—The January issue of the "Obermayer Bulletin" of foundry information, published and issued by the S. Obermayer Company, Cincinnati, O., contains a number of most interesting articles on different phases of foundry practice, which are written by practical men skilled in the subject. This bulletin will be sent free to any foundryman who desires it.

Second-Hand Machinery.—The Niles-Bement-Pond Company, 111 Broadway, New York, is issuing list No. 15 of second-hand metal working machinery. This includes a brief, but complete, description of 340 different machine tools, including practically all designs and sizes of metal working tools, The present location of the machine, its weight and its general condition are included.

Belt Conveyors.—The Jeffrey Mfg. Co., Columbus, O., is issuing a booklet largely given up to illustrations of installations of rubber belt conveying machinery for handling material of various kinds. The wide range of usefulness, and the large capacity, of this type of conveyor is clearly shown in the photographs. Prices of the belts and rollers of different designs are included.

Steel Tires.—A paper read before the Western Railway Club, on October 18, 1907, by Mr. George L. Norris, on the subject of "Causes of defects and failures of steel tires," has been reprinted in a standard size booklet by the Standard Steel Works, Harrison Building, Philadelphia. This paper was a most complete presentation of the subject and included a large number of illustrations. The discussion of the paper is also included.

Calendars.—Among the calendars received for the current year the ones from the following named companies are especially noticeable: The American Wood Working Machinery Company; H. B. Underwood & Co.; Flannery Bolt Company; Bangor & Aroostook Railway Company; Hazard, Cotates & Bennett Company, and the Falls Hollow Staybolt Company. The latter is an excellent reproduction of a famous painting by Franz Charlet entitled "The First Days of Spring."

Steam Gauges and Valves.—The American Steam Gauge & Valve Mfg. Co., 208 Camden St., Boston, Mass., is issuing a new 246 page cloth bound catalog, completely illustrating and describing the large variety of gauges, valves, indicators, and kindred appliances for governing, indicating, measuring, recording and controlling steam, water, air, gas, oil, ammmonia and other pressures, manufactured by it. The information in the catalog is most complete and it should be available for reference by every one having anything to do with these appliances.

Air Brake Lubrication.—The Joseph Dixon Crucible Co., Jersey City, N. J., is issuing an attractive leaflet, printed in two colors, under the above title. The descriptive matter includes a description of the air brake testing rack at Purdue University and gives an account of tests made with Dixon flake graphite on it. Following this is a description of the value of air brake and triple valve grease and a note as to the parts of the air brake system on which it can be used to advantage. Several pages are given up to a discussion of the lubrication of air pumps.

Record No. 64.—The Baldwin Locomotive Works has recently issued a new record which includes a brief history of the Central Railroad of Brazil, and gives illustrations and complete descriptions of the large number of locomotives which have been built for that company by the Baldwin Locomotive Works. These include many types and designs for both narrow and full gauge tracks. This company has furnished altogether 296 locomotives for this road. The company, through its extra work department, also furnishes parts for repairs for all of these locomotives.

Shay Geared Locomotives.—The Lima Locomotive & Machine Company, Lima, O., is issuing one of the most attractive standard 6 x 9 in. catalogs that has come to our notice. This catalog bears the No. 151 and contains illustrations of a large number of locomotives, together with the principal dimensions and hauling capacities of both Shay geared and direct connected or rod types, built by this company. The standard specifications for construction, as well as some other useful general information is also included. This company builds logging cars as well as locomotives.

Journal Boxes.—The T. H. Symington Co., of Baltimore and Chicago, have recently published an attractive catalog, briefly worded, but illustrating very fully by half-tone cuts the various types of Symington journal boxes which it manufactures to suit different classes of service. Its now well known "torsion spring" lid is recommended for freight service and the "Pivot" lid for passenger cars and locomotive tenders. In addition attention is called to this company's ability, as specialists and experts in the line of journal box manufacture, to furnish boxes of any design desired.

"The Man Who Didn't Know When He Had Failed."—A most artistic and attractive booklet bearing the above title has been received from the Carborundum Company. It is a very interesting story by Mr. F. W. Haskell, reciting the development of the manufacture of carborundum. This substance fifteen years ago was sold by the carat and commanded a price of $880,000 a ton and the total world's output at that time was four ounces a day. From that beginning the present Carborundum Company was evolved, which has an output of ten million pounds a year. The booklet is illustrated with appropriate marginal sketches.

Longest Narrow Gauge Railway.—The Arthur Koppel Company, Machesney Building, Pittsburg, Pa., is issuing a pamphlet containing a reprint from the London *Engineering*, which describes the features of construction of the longest narrow gauge railway in the world, built by this company in German-Southwest Africa and known as the Otavi Railway. It is a most interesting piece of construction and the rolling stock as well as the bridges, yards and track work, are thoroughly illustrated and described in this article. The work was accomplished under the most difficult conditions of climate and labor and reflects great credit on this company.

Springs.—The Standard Steel Works, Harrison Building, Philadelphia, Pa., is issuing a standard size catalog on the subject of springs for steam or electric railways. It illustrates several of the more important designs of elliptical, semi-elliptical and coiled springs which are now in use on steam and electric roads; gives a brief description of the salient features of each design, and also includes views of the spring department of these works. The large capacity of the storage racks, which permits the carrying of sufficient quantities of flat and round bars to meet the heavy demands, puts this company in a position to start work immediately upon any design of springs desired without any delays occasioned by the non-arrival of bars from the steel mills.

The Weathering of Coal.—Bulletin No. 17 of the Engineering Experiment Station of the University of Illinois, which relates to the weathering of coal and the losses in fuel values which accompany storage under various conditions, has just been issued. This recounts a series of tests by S. W. Parr and N. D. Hamilton, which add materially to the information on this subject and gives a much better understanding of matters pertaining to weathering, spontaneous combustion and other difficulties which attend the storage of coal in large masses. Other bulletins being issued by the University are No. 19 on comparative tests of carbon, metallized carbon and tantalum filament lamps, and No. 16 which presents the results of several years study on trussed roofs by N. Clifford Ricker, professor of archcitecture at the University. The bulletins can be obtained upon request.

Electrical Machinery.—Among the many bulletins being issued by the General Electric Company might be mentioned bulletin No. 4559 on the subject of direct current motor starting devices. These are improved instruments and are very completely illustrated and described in this bulletin, practically any desirable design being obtainable. Also buletin No. 4564 on the subject of centrifugal air compressors. These are low pressure machines, having a rating from .88 to 4 lbs. per square inch and a capacity from 750 to 10,000 cu. ft. of free air per minute. These sets are furnished driven either by Curtis steam turbines, direct current motors or induction motors. They are for either pressure or exhauster service, being specially adapted for ventilation. Bulletin No. 4562 is on the subject of mill type motors, which are built in sizes from 30 to 150 h. p., in either direct or alternating current types. These motors are specially designed for very heavy intermittent loads; are completely enclosed and dust proof.

LOCOMOTIVE FUEL ECONOMY

"Of the one hundred million tons of coal used in the railway locomotives each year, not more than five per cent. of the heat developed is converted into the actual work of pulling trains, yet these railways must annually haul three million cars of coal to keep these locomotives moving."

The purpose of this article, or study, is to present the importance of the locomotive fuel question as forcibly as possible and to direct attention to the great possibility of savings which may be made in that direction. An attempt has been made to bring out the best practices in use, or in the process of being developed, on different railroads in connection with the various phases of this question—from the purchase of the fuel to its use on the locomotive. Where reports of experts were available as to any part of the problem, and it is a large one, they have been made use of. A study of the locomotive fuel question, no matter how complete it may be, cannot be considered as having exhausted the subject, because of the crude state of the problem and the fact that developments must surely take place, especially at a time like this when the railroads are forced to closely examine into possible economies.

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Importance of the Locomotive Fuel Question.

Fuel for locomotives is the largest single item of expense in the cost of conducting transportation on most of our American railroads. The table on the following page has been compiled from the annual reports of several of the larger railroad systems in different parts of the country, to give a clear idea of the importance of this item. For the nineteen roads the cost of fuel on the locomotive tender amounted to $92,492,098, or 11.42 per cent. of the total operating expenses of these roads. The next most important item in the cost of conducting transportation is the combined wages of enginemen and roundhouse employees. For the first seventeen railroads included in the table this item amounts to $67,369,934 as compared to $80,554,716, the cost of fuel. In arranging the table several large systems in each part of the country have been selected.

A study of the ratios of the cost of fuel to the total operating expenses brings out some interesting facts. The ratio is highest (from 13 to 17 per cent.) on the New England and Middle Western roads and on the Seaboard Air Line. It is lowest on the Chesapeake & Ohio (7.81), Louisville & Nashville (8.01), Pennsylvania Railroad (9.25), and Baltimore & Ohio (9.34). On the other roads it ranges between 10 and 13 per cent. On fifteen of the nineteen roads the wages of enginemen and engine house men combined is less than the cost of fuel—in some instances very much less. On the Pennsylvania Railroad these two items are about equal, while on the Baltimore & Ohio, Chesapeake & Ohio and Louisville & Nashville, the wages are higher than the cost of fuel.

It would be reasonable to suppose from the importance of the fuel item that the railroads as a whole would devote considerable attention to its inspection, handling and economical use. It is surprising, therefore, to find how little attention is given to this question and how little its importance seems to be appreciated. The fuel resources of this country are not unlimited and the cost of fuel is advancing. Reduced rates and increased cost of labor and material make it necessary for the railroads to study possible economies closely, and there seems to be no more promising field than this item of fuel—from its purchase to its use on the locomotive. Several of the railroads have recently started to take active steps in the direction of fuel economy. Most of these have concentrated their entire attention on some particular phase of the question, such as inspection, distribution, handling or use of fuel. The purpose of this article is to bring out the best practice in these different branches, or departments, and to present the whole question in as complete and logical a form as possible.

Mining and Utilization of Fuel.

By Dr. J. A. Holmes.

(At the December, 1907, meeting of the American Society of Mechanical Engineers Dr. J. A. Holmes, of the United States Geological Survey, in discussing the paper on "The Rational Utilization of Low Grade Fuels," presented by Mr. F. E. Junge, of Berlin, Germany, called attention to the investigations made by the Government dealing with wastes that are taking place in the mining and utilization of coal. The present condition of the fuel resources of this country and some of the larger wastes that are taking place, were so clearly stated that his remarks are reproduced quite fully, and are recommended for the earnest consideration of those who are interested in the fuel question.)

The investigations that have been conducted at St. Louis, at Norfolk, and at Denver, during the past three years, had for their cardinal purpose the comparison of one character of fuel with another. It was hoped—and in part only was that hope realized—that the engineering investigations would give us results even more valuable than they were; but the equipment which we were compelled to use in the beginning was selected because it represented the ordinary power plant in use in the United States, and the comparisons of the various fuels have been made on this equipment with only such slight modifications as were feasible at the time.

It has been common to find, where there is a vein eight feet in thickness, that two or three feet is left unmined and is permanently lost, because of the subsequent caving in of the mine. We have found, furthermore, that there is no sharp line drawn between high grade and low grade fuels; that in certain mines the amount of coal left unmined, under the ground, exceeded 75 per cent. of the total available coal, and the average result is

ITEMS OF INTEREST TO MECHANICAL DEPARTMENT OFFICIALS, TAKEN FROM THE ANNUAL REPORTS OF A NUMBER OF RAILROADS, AND SHOWING FORCIBLY THE IMPORTANCE OF THE ITEM "FUEL FOR LOCOMOTIVES."

NAME OF ROAD.	Boston and Maine.	N.Y.,N.H. & H. RR.[4]	N.Y.C. & H. R.R.	Erie.	P. R.R.	B. & O. R.R.	C. & O.	Seaboard	So. Ry. Co.	L. & N. R.R. Co.
Annual report—year ending	6-30-07	6-30-07	12-31-06	6-30-07	12-31-06	6-30-07	6-30-07	6-30-07	6-30-07	6-30-07
Mileage operated	2,288	2060.1	3783.9	2168.8	3819.68	4006.3	1827.4	2610.9	7546.8	4306.3
Gross earnings from operation	41,125,256	55,601,936	92,089,768	51,194,113	148,239,882	82,243,921	25,796,860	16,427,942	56,657,994	48,263,945
Expenses—operating[1]	30,968,397	37,850,081	64,953,695	33,579,958	101,805,644[5]	54,880,090	16,650,306	12,948,041	43,068,547	35,781,302
Net earnings from operation	10,156,859	17,751,854	27,136,073	17,614,155	46,434,238	27,363,830	9,146,554	3,479,900	13,589,447	12,482,642
Ratio expense to earnings	75.3	68.07	70.53	65.60	68.68	66.73	64.54	78.82	76.01	74.17
Operating expenses: Main. of way and structures	4,905,226	5,479,089	10,718,599	5,087,974	17,060,498	10,542,498	3,090,037	2,205,997	7,660,168	8,065,898
Per cent. of total expense	15.84	14.48	16.50	15.15	16.75	19.21	18.56	17.04	17.79	22.54
Maintenance of equipment	4,305,913[3]	5,638,784	14,569,057	8,147,536	26,201,244	13,448,502	4,721,345	2,314,914	9,576,041	8,709,610
Per cent. of total expense	13.90	14.89	22.43	24.25	25.73	24.50	28.35	17.88	22.23	24.34
Conducting transportaion[1]	20,830,959	25,286,306	37,267,589	19,075,407	55,276,180	29,380,155	8,437,507	7,827,312	23,941,599	17,972,347
Per cent. of total expense	67.26	66.81	57.38	56.83	54.29	53.54	50.68	60.45	55.59	50.23
General expense	926,296	1,445,902	2,398,449	1,269,039	2,835,334	1,508,934	401,415	599,816	1,890,739	1,033,445
Per cent. of total expense	3.00	3.82	3.69	3.77	2.78	2.75	2.41	4.63	4.39	2.88
Maintenance of equipment expen's in detail: Superintendence	129,298	155,926	297,691	286,653	776,631	260,552	89,623	68,918	181,144	203,688
Locos., repairs & renewals	1,367,598	2,264,160	5,587,769	3,170,627	8,585,298	4,653,638	1,320,110	852,908	3,504,922	2,757,091
Cars, pass., rep. and ren.	729,935	1,139,476	1,767,055	670,801	2,308,239	966,328	314,051	276,217	814,678	565,016
Cars, freight, rep. and ren.	1,040,332	1,243,481	5,347,237	3,574,031	12,290,906	6,586,610	2,741,990	710,667	4,549,030	3,578,067
Cars, work, rep. and ren.	35,978	34,231	90,512	54,615	263,831	152,451	24,904	39,313	75,710	76,762
Floating equipment	4,172	185,481	416,598		449,120	215,474	15,202	4,220	20	
Tools and mchy., repairs	56,835	183,960	437,337	259,732	771,013	355,263	127,122	84,501	286,393	198,274
Other expenses	200,093	432,065	624,855	120,408	756,203	258,183	88,340	123,167	164,141	228,558
Injuries to persons				10,667						20,547
Improve., new equip., etc.								155,000		1,081,604
Conducting trans. items of interest to mech. dept.: Engine house men	3,031,318	3,309,225	1,069,719	958,561	1,838,204	916,336	300,035	115,137	4,002,000	614,641
Engine men			5,117,517	2,854,398	7,599,581	4,976,562	1,478,010	887,996		2,667,403
Fuel for locomotives[2]	5,269,823	5,322,325	6,875,590	4,329,168	9,418,285	5,124,445	1,301,155	1,896,288	4,717,681	2,866,037
Locos., water supply	184,727	316,512	438,556	212,565	777,049	324,517	132,729	77,489	294,905	184,345
" stores for					304,900	249,320	79,938	69,460		
" other supplies	123,633	187,551	425,868	246,399	410,218	185,181	60,255		224,031	245,838
Ratio fuel to opera'g exp	17.01	14.06	10.58	12.89	9.25	9.34	7.81	14.64	10.95	8.01
Locos., number	1,073	1,176	2,075	1,384	3,215	1,837	670	398	1,536	865
" tractive power				43,490,311	94,880,283	57,169,677				
" mileage	32,647,960		68,200,265	34,437,505	96,099,303	64,244,352	18,742,322	12,507,308	46,460,363	
" Cost per mile in cents	31.21			34.31		25.6	23.23	31.44	28.09	
Average cost of fuel per ton			1.70					2.60		
Cars, passenger, number	1,719	2,202	2,243	1,096	2,072	1,078	301	333	995	559
" freight "	20,782	19,776	69,070	51,514	119,036	78,704	31,593	12,411	56,225	39,528
" service "	537	1,056	3.220	1,955	3,526	2,707		615	1,292	1,452

NAME OF ROAD.	Wabash.	L. S. & M. S. Ry.	C. M. & St. P.	C.& N.W.	C. R. I. & P.	Missouri Pacific.	A. T. & S. F. Ry.	Union Pac.	So. Pac. Co.[7]
Annual report—year ending	6-30-07	12-31-06	6-30-07	6-30-07	6-30-07	6-30-07	6-30-07	6-30-07	6-30-07
Mileage operated	2514.3	1520.3	7049.4	7550.6	7780.2	6375.1	9273.1	5644.5	9400.5
Gross earnings from operation	27,432,473	42,544,378	60,548,554	68,878,931	60,238,419	48,703,342	93,683,406	75,651,105	117,331,812
Expenses—operating[1]	19,505,147	27,252,077	39,400,410[6]	44,789,025	41,044,142	32,515,070	58,867,901	40,155,522	73,631,374
Net earnings from operation	7,927,326	9,868,577	21,148,144	24,089,906	19,194,277	16,188,272	34,815,505	35,495,583	43,700,438
Ratio expense to earnings	71.10	64.06	65.07	65.03	68.13	66.76	62.84	53.08	62.75
Operating expenses: Main. of way and structures	2,747,667	5,322,562	5,830,967	8,904,940	8,754,396	5,906,120	15,286,062	10,066,868	16,031,877
Per cent. of total expense	14.08	19.53	14.80	19.88	21.33	18.16	25.96	25.07	21.77
Maintenance of equipment	3,915,261	5,843,734	8,589,757	8,713,026	7,184,128	6,998,863	11,779,846	7,853,933	15,017,190
Per cent. of total expense	20.07	21.44	21.80	19.46	17.50	21.52	20.01	19.55	20.39
Conducting transportaion[1]	12,153,324	15,376,192	22,782,468	25,990,596	23,420,948	17,595,101	29,538,964	20,276,530	39,238,101
Per cent. of total expense	62.31	56.42	57.82	58.03	57.07	54.11	50.18	50.50	53.29
General expense	688,894	709,588	1,250,349	1,180,461	1,684,668	2,014,985	2,263,027	1,958,191	3,344,204
Per cent. of total expense	3.53	2.60	3.17	2.63	4.10	6.20	3.84	4.88	4.54
Maintenance of equipment expen's in detail: Superintendence	102,265	175,512	100,884	178,994	279,729	234,699	599,290	751,962[8]	1,069,770[8]
Locos., repairs & renewals	1,520,346	1,756,427	2,590,947	2,394,785	3,171,376	3,212,112	4,697,673	2,779,348	5,989,492
Cars, pass., rep. and ren.	271,693	613,374	832,390	622,669	740,244	516,776	941,486	697,473	1,503,692
Cars, freight, rep. and ren.	1,120,557	2,693,946	4,505,838	4,830,198	2,431,538	2,533,328	4,415,645	3,129,943	4,934,229
Cars, work, rep. and ren.	21,238	106,877	73,367	85,878	152,034	106,375	136,700	139,330	345,356
Floating equipment	17,972	7,007		1,198	2,772	25,479	23,572		536,454
Tools and mchy., repairs	128,122	201,599	224,920	194,617	225,888	284,923	315,844	355,875	638,193
Other expenses	197,451	288,990	253,934	365,231	132,542	83,218	649,582		
Injuries to persons				39,452	48,002	11,706			
Improve., new equip., etc.	535,613								
Conducting trans. items of interest to mech. dept.: Engine house men	1,951,866	422,091	4,064,235	939,257	3,915,181	738,208	895,517	3,833,238[9]	7,458,589[9]
Engine men		2,033,532		3,940,753		2,531,932	4,200,719		
Fuel for locomotives[2]	2,272,041	3,089,422	5,325,673	6,218,724	6,013,600	3,782,688	6,123,504	5,169,701	7,375,948
Locos., water supply	117,627	190,783	215,273	302,456	338,701	236,410	596,513		
" stores for									
" other supplies	104,764	168,072	207,572	272,847	317,265	247,594	393,108		
Ratio fuel to opera'g exp	11.64	11.33	13.51	13.88	14.65	11.63	10.40	12.87	10.01
Locos., number	622	821	1,017	1,422	1,343	1,068	1,791	1,051	1,759
" tractive power	14,170,797				33,058,752	28,862,350	52,341,975		
" mileage	22,769,821	28,095,159			41,141,517		51,570,692	32,357,330	57,488,094
" Cost per mile in cents	24.84	26.63			34.48		33.14	37.44	37.25
Average cost of fuel per ton	1.41	1.66			2.188		1.61		2.91
Cars, passenger, number	441	614	1,089	1,311	878	693	1,135	643	1,707
" freight "	24,401	35,586	44,626	58,637	41,261	37,318	49,991	25,377	43,757
" service "		1,468	222		2,956	4,811		2,929	4,517

[1] Not including taxes. [2] Including operation of fuel stations. [3] Includes $741,668 for new equipments. [4] Steam lines only. [5] Includes Delaware and Raritan Canal. [6] Includes $946,867 for additions to property. [7] Rail lines only. [8] Superintendence and other expenses. [9] Locomotive service other than fuel.

As far as possible, several roads have been selected from each section of the country. Statistics of this kind are of use for general comparisons only, since the methods of accounting, in force on the different roads when the annual reports, from which these figures were taken, were compiled, differed more or less. Under section 20 of the act to regulate commerce the Interstate Commerce Commission has provided a standard system, or classification, for accounting for the use of the railroads. This went into effect July 1, 1907. Statistics compiled in accordance with this act, when they are available, will prove of great value for the purposes of comparison.

The cost of the locomotive per mile run is taken directly from the reports and includes the cost of fuel, oil and supplies, wages of engineers, firemen and wipers, and repairs and renewals.

In 1906 400,000,000 tons of coal were mined in the United States. During the same period the railroads used about 100,000,000 tons of coal for locomotive fuel, or 25% of the total output.

that at least 50 per cent. of the possible coal supply in these veins is left under the ground and unrecoverable. I recall one case in particular in which out of a possible 25-foot vein of coal, only four feet were taken out, because of unskillfulness in mining, and the rest left underground and practically destroyed. The carelessness with which coal miners have gone to work mining the lower seams and allowing cave-ins to follow, has had the result of leaving the coal in the higher seams unmined and practically lost because of the caving-in of the adjacent material. In West Virginia, and in Ohio, and in various other places, the cost of mining has been greatly increased, entirely out of proportion to the amount of coal that has been mined, because of this carelessness.

I desire to call attention to the possibility of utilizing these coals by the location of plants at the mines, thus avoiding the cost of transportation. Consider a single illustration. Take the Pennsylvania Railroad, which uses 40,000 tons of coal every day in its own locomotives. If, as is now being attempted, all of that power can be generated from low grade fuels not now utilized at all, we shall see an enormous gain in the direction of a solution of our fuel problems and our problem of transportation would be vastly simplified. Consider for a moment what the application of this same thought would mean to the 100,000,000 tons of coal now annually consumed in our locomotives.

Very few persons realize that so rapidly is the fuel industry developing that during each succeeding decade for the past eighty-five years the amount of coal mined and used in the United States has equaled that of all the preceding decades; so that the amount of coal mined and used between 1895 and 1905, was equal to that mined and used during the preceding seventy-five years. Now, there has not been a corresponding increase in efficiency, nor has there been any marked gain in the utilization of the low grade materials. What we are doing at the present time is skimming the surface, using the high grade coals and leaving the low grade coals—using the surface coals and leaving the deeper coals. Therefore, we are approaching a condition where our coal cost will be greatly increased and the amount of available high grade coal very much diminished. I am not now prepared to say when that time will come, but we trust that our coal supply will last as long as that of any other country; still we must awaken to the fact that our high grade coals are passing so rapidly, that coal lands used for supplying coke and for other special purposes, in Maryland and in West Virginia, cannot be purchased in many sections for less than $1,500 to $2,000 an acre.

I may say, in conclusion, that while these investigations have been in part under the supervision of this and the allied engineering societies, the President of the United States has, in his message to Congress, recommended the establishment by the Government of a special bureau for mining and engineering investigation, in which the work initiated at St. Louis in a crude way may be placed upon the highest possible plane as to equipment and mining and engineering data. It is proposed, furthermore, that this new bureau shall be independent, and shall be placed entirely under the supervision of the representatives of national engineering societies and other allied bodies, who, together with those chiefs of Government bureaus who have to do with actual construction work, shall direct the energies of the department.

Government Fuel Investigations.

A brief statement of the purposes of the Government fuel investigation and what has thus far been accomplished may be of interest in connection with Dr. Holmes' remarks.

The purposes of these investigations are:

To lessen the waste of the nation's fuel supply by showing how fuels can be mined and used more efficiently.

To extend the nation's supply of fuel, and lessen the transportation cost by indicating how lignite, peat and other materials, now little used, may become locally valuable as fuels in portions of the country having no ordinary coal.

To find how to prevent the spontaneous combustion of coals in storage, on ships, naval stations, at the mines, etc.

To remedy the loss sustained in the production of fine coal in mining through slacking, etc.

To demonstrate the saving of by-products now wasted in the manufacture of coke, which if completely saved would be worth at present prices more than $50,000,000 yearly, and prevent large imports of such by-products.

The present waste of fuel:

Approximately 50 per cent. of the possible coal supply is now lost by being left underground or wasted before reaching the furnace.

Of many Mississippi Valley and western coals from 30 to 50 per cent of the total product mined comes out in the form of "slack" which is often sold at less than cost, or accumulates and is burned about the mines.

Of the fine portion of these Mississippi and western coals put into furnaces often 10 to 25 per cent. is unconsumed and lost in the ashes.

Of all the coal actually burned only about 5 per cent. of the heat units are actually converted into work.

In the coking of 40,000,000 tons of coal yearly, there are now wasted ammonium sulphate enough to fertilize our crops; creosote enough to preserve our timbers; pitch and tar enough to roof our houses and briquette our slack or waste coals.

Some benefits resulting from this work. It has demonstrated:

The possibility of utilizing for power purposes the large and undeveloped areas of lignite and low grade coals of the west and southwest.

The practicability of using in gas producers, for power purposes, ordinary bituminous coals and lignites, and of thus obtaining from each ton of coal more than 2½ times as much power as is obtainable in ordinary steam power plants.

The possibility of making coke from a number of coals not considered generally as coking coals.

Some of these results are not only new, but were believed to be impracticable when these investigations were begun. These and other results are worth to the country many hundred times the total cost of this work.

The Grade of Fuel to Use in Locomotives.

One of the most important considerations in connection with the question of fuel economy is the selection of the proper grade of fuel. It must be fairly uniform in quality or it will be impossible to use it economically. A front end arrangement, or grates suitable for one grade of coal, may be entirely unsuited for another and the fireman cannot obtain good results where the grade of fuel is constantly changing.

Ordinarily it is not possible for the railroads to secure a run of mine coal. A 5 or 6 in. screen is used at most of the mines and the larger coal is used for commercial purposes. The mines can usually insist on this because the railroads can secure a long haul on the superior grade of coal. On the other hand the mine operators are anxious to make contracts with the railroad company to insure keeping the mines in operation during the summer months when the commercial requirements are light. During the dull period the work is usually confined largely to the making of headings and the opening of new rooms and in getting things in shape to be pushed when the heavy demand comes. The railroads thus often secure a better grade of coal during the summer months than during the remaining part of the year. While there are instances where it might be in the interests of economical locomotive performance to confine the buying of coal to certain mines, yet the development of the district and the building up of traffic along a certain part of the line might make it advisable to secure coal from other mines. While the railroads usually do not get the best grade of coal, they pay less for it. Roughly, the mine operators get from 10 to 40 per cent. more for commercial coal than for railroad coal.

While the above considerations are important they should not be allowed to overshadow the desirability and importance of

buying the coal on a heat value basis. There is a great difference in the heat value of different coals, and while the subject has been given very little attention by most of the railroads, it is of prime importance. It is of interest to note that as a result of coal tests made at St. Louis by the United States Geological Survey, the Government is purchasing coal for about forty departmental buildings in Washington, and for public buildings throughout the country on a simple specification, the prime elements in which fix the amount of ash and moisture in anthracite at seven per cent. Premiums are paid for any decrease in the ash content up to two per cent. above the standard, and corresponding penalties are fixed for any increase in ash above the standard. Better and more complete specifications, but more difficult for the dealer to fulfil, have been fixed by a few of the largest manufacturing and power concerns of the country, in which penalty and premium are paid not only on account of ash and moisture content, but also on the basis of the British thermal units as specified in the contract.

It is possible, on a railroad, to make simple evaporative tests in actual service by which the comparative heat values of the different coals may be determined. These results will enable the railroads to place their coal contracts to the best advantage. The extent to which the heat value should govern in the purchase of the coal is considered in the section on "Distribution."

M. N. Forney, in an article in this Journal, in June, 1901, had this to say concerning the most economical coal to use on a railroad: "If, through an accident, an employee or passenger should have his toes cut off and should make a claim for damages, the most skilful legal counsel and expert testimony would be devoted to the defense of the company, and to resisting the payment of the value of the lost toes; but the cases in which railroad managers have been willing to pay anything at all to an expert to tell them how they could save a hundred or a thousand times the amount of his fees, by indicating which was the most economical coal to use, are very few. One reason for this, in some cases, is that the award of contracts for supplying coal is decided with loaded dice, and contracts are given to parties who have 'influence' at headquarters. However that may be, it is certain that it would be immensely profitable to almost any railroad company to give thorough and intelligent investigation to the quality of fuel used on its line."

Fuel Tests.

In determining the heat value of the different grades of coal used on the railroad, evaporation tests should be made on a locomotive in preference to laboratory calorimeter tests. The actual burning of the coal in large quantities under service conditions may be attended by features which would make it impossible to obtain the full value of the heat units, as shown by the calorimeter tests. More reliance would also be placed on an actual test of 100 or more tons of coal, as compared to 6 to 20 one-gram samples taken from 200 or 300 lbs. of coal.

A practical and successful method of making locomotive evaporation tests may best be explained by quoting from a paper on "The Influence of Heat Value and Distribution on Railway Fuel Cost," presented before the Western Railway Club in November, 1907, by J. G. Crawford, fuel engineer of the Chicago, Burlington & Quincy Railroad.

"The coals should be tested in groups, and in order that different groups of coals may be compared, even though the tests are made 1,500 miles apart, each group of tests, as well as the individual tests, should be carried on under similar conditions. The unit of comparison for coals is the number of pounds of equivalent water evaporated per pound of coal. It is evident that the following items will affect this ratio or unit of comparison: Kind of coal; class of engine; condition of engine; engine crew, especially the fireman; class of service. Since the object of coal tests is to determine the comparative value of various coals, all of the above conditions should be kept as uniform as possible. These items will be referred to below.

Selection of Division for Tests.—"Coals should be tested on a division where they are being used, as the firemen are already accustomed to them. When coals which differ materially from those habitually used are to be tested, a number of trial runs must be made until the firemen can properly fire the coal.

Class of Engine.—"If possible all the tests made on one railroad system should be made on one class of engine. This is advisable in order that the coals tested at one end of the system can be compared with those tested at the other end without having to correct for the difference in evaporative efficiencies of the engines.

Condition of Engine.—"Engines should always be in good condition, and this applies especially to condition of flues and firebox. Whether a brick arch is used or not, the conditions in this particular should be the same in all tests.

Engine Crews.—"During a series of tests the same firemen should be used throughout, thus avoiding any difference on this account. It is not so important that the same engineers be used, for while one engineer may use more steam than the other, the ratio of the coal to the water used will not change materially.

Class of Service.—"Passenger is preferable to freight service on account of the more uniform conditions. It is desirable that the time between terminals, the time using steam and the weight of the trains shall be nearly uniform from day to day, and that the average of these values for all tests made with each kind of coal shall be nearly the same. When tests are conducted in freight service at least twice the length of time will be required to test one kind of coal, and the expense will be more than doubled on account of additional coal weighers being required.

Organization of Test Party.—"At each terminal a fuel tester is located to take charge of the supply and weighing of the test coal and to see that none of the weighed coal on the engine is used during its stay at the terminal. The coal weigher is relieved by an engine observer before the engine leaves the roundhouse, and he stays with the engine until relieved by the coal weigher at the other terminal. The engine observer keeps record of coal, water, steam pressures, stops, shut-offs, etc., in a printed thumb-indexed note book made up of seven printed forms and three blank pages. The note book and details of the individual pages are shown in Fig. 1. From four to eight men are required to make the tests properly, according to whether one or two engines are used and whether they are single or double crewed.

Number of Tests.—"Exclusive of that used for firing up, about 150 tons of each kind of coal should be used on the tests. From six to eight round trips should be made with each coal, and where two firemen are used half the tests should be made with each fireman. This is necessary, as one fireman might be slightly better than the other. Tests in one direction on account of grades, speed or number of cars may be more favorable than in the other, hence the same number of trips in each direction are necessary.

Results.—"The data taken for each test are recorded on blanks, shown in Fig. 1, and the more important totals and averages recorded on the final result sheet of which Fig. 2 is a reproduction. The data and computations of each test are recorded in a column and the average for all tests in the average column. In a series of tests which have all been conducted under similar conditions, the heat value of each coal is proportional to the average of items No. 35 which shows the equivalent number of pounds of water evaporated from and at 212 degrees per pound of coal."

While the above tests are possibly more elaborate than some of the smaller roads would care to undertake, results of considerable value may be obtained from tests made by one or two men. It is essential, however, that the firemen be familiar with each coal before the test trips are made and that several test trips be run with each coal in order to secure fair average results.

By testing the coal in passenger service the tests may be made in from one-third to one-half the time required in freight service, and there is no reason why the tests should in any way delay the passenger trains. The difference in the kind of service should not affect the comparative efficiency of the coals to any great extent, but all of the tests should, of course, be made in the same class of service.

COAL

WEIGHT OF TENDER
- AT START (AT SCALES)
  - LOADED ______ #
  - EMPTY ______ #
- (A) IN PIT AT START ______ #
- AT FINISH (AT SCALES)
  - LOADED ______ #
  - EMPTY ______ #
- (B) IN PIT AT FINISH ______ #

CHARGE TO TRIP

(A) MINUS (B) ______ #

SACKED COAL ______ #

LOOSE COAL AHEAD OF GATE ______ #

CORRECTION ACCOUNT OF WATER LEAKING FROM TANK BETWEEN "EMPTY" AND "LOADED" WEIGHINGS AT START ______ #

TOTAL CHARGES ______ #

CREDIT TO TRIP

COAL USED FROM PIT BEFORE STARTING ______ #

COAL SAMPLE ______ #

COAL FELL OFF TENDER ______ #

COAL USED FROM PIT AFTER ARRIVING AT DEPOT AND BEFORE WEIGHING ______ #

CORRECTION ACCOUNT OF WATER LEAKING FROM TANK BETWEEN "LOADED" AND "EMPTY" WEIGHINGS AT FINISH ______ #

TOTAL CREDITS ______ #

NET COAL USED ______ #

LEAKAGE OF WATER BETWEEN WEIGHINGS

	EMPTY	LOADED	TANK LEAKAGE PER MINUTE
START			
FINISH			

NOTES: SACKS WEIGH ______ # EACH

IN ESTIMATES USE WEIGHT OF A SHOVEL-FULL ______ #

FIRE HAD ABOUT ______ # MORE / LESS COAL AT FINISH THAN AT START

COAL FROM CAR ______ KIND ______

WATER WASTES

INJECTORS	LOSS PER APPLICATION	NO. OF APPLICATIONS	TOTAL WASTES
RIGHT	#		#
LEFT	#		#

LEAKAGES	RATE PER MINUTE	NO. OF MINUTES	
TANK HOSE	#		#
" "	#		#
TANK	#		#
"	#		#
MUD RING	#		#
" "	#		#

HOT BEARINGS

______ # ______ #

______ # ______ #

OTHER WASTES

______ # ______ #

______ # ______ #

TOTAL WASTES ______ #

RECORD OF INJECTOR APPLICATIONS

RIGHT ______

LEFT ______

GENERAL

TRAIN ______ ENGINE ______ DATE ______

ENGINEER ______ FIREMAN ______

CARS

NUMBER	FROM	TO

WEATHER

	START	FINISH	AVERAGE
TEMPERATURE OF AIR			
BAROMETER—INCHES			
" —POUNDS			

RAIN OR SNOW

FROM	TO	HEAVY OR LIGHT

MISCELLANEOUS

ASH PAN DUMPED	FIRE CLEANED	GRATES SHAKEN

HAS ENGINE A BRICK ARCH? ______

SIZE OF EXHAUST TIP? ______

COAL SAMPLE IN CAN # ______ TO ENG R TESTS

REPORT OF COAL SACKS

	LOADED	EMPTY	TOTAL
ON ENGINE AT START			
" " " FINISH			
ON HAND AT N. or E. TERM			
" " " W or S. "			

	PLACE	SIGNATURE
COAL WEIGHER		
" "		
ENGINE RIDER		

SHUT-OFFS

PLACE	MINUTES	REMARKS

TIME IN MOTION ______ HRS. ______ MIN

" " SHUT-OFF ______ HRS. ______ MIN

" " USING STEAM ______ HRS. ______ MIN.

STEAM PRESSURES

___ M.	___ M.	___ M.
00	00	00
10	10	10
20	20	20
30	30	30
40	40	40
50	50	50
00	00	00
10	10	10
20	20	20
30	30	30
40	40	40
50	50	50
00	00	00
10	10	10
20	20	20
30	30	30
40	40	40
50	50	50

	OBSERVED	CORRECTED	ABSOLUTE
AVERAGE	#	#	#
MAXIMUM	#	#	
MINIMUM	#	#	

STOPS

PLACE	ARV.	LV.	LENGTH OF STOP	REMARKS

TIME ON ROAD ______ HRS. ______ MIN.

" OF STOPS ______ HRS. ______ MIN.

" IN MOTION ______ HRS. ______ MIN.

NO. OF STOPS ______

WATER RECORD

PLACE	TEMP.	INCHES	WT. LBS.	AMT. DRAWN

AVERAGE ______ °

TOTAL - - - - - - - - - ______ #

CORRECTIONS

WATER WASTED ______ #

WATER IN GAUGE GLASS ______ #

TOTAL - - - - - - - ______ #

WATER APPARENTLY EVAPORATED ______ #

NOTE. WATER AT END OF RUN WAS ______ INCHES { HIGHER / LOWER } IN GLASS THAN AT START.

FIG. I.—BLANKS FOR RECORDING OBSERVATIONS OF LOCOMOTIVE FUEL TESTS.

Inspection at the Mines.

Fuel for locomotives is the largest single item in the cost of conducting transportation, except on some of the eastern roads, where the item of wages for enginemen runs as high and in some instances slightly higher. On a large railroad the inspection branch of the mechanical department cost last year 1½ per cent. of the value of all the material used in that department, subject to inspection. The coal inspection for the same time cost only one-twelfth of one per cent. of the fuel bill.

There is no question but that the possibilities of saving due to a careful inspection of fuel are very great, and yet few of the roads have taken any important steps in this direction.

Under present conditions the mines are, in many instances, able to unload a lot of undesirable and oft-times worthless coal on the railroads simply because they know it will not be detected until it gets to the fireman, and then, although he may complain, there is no one whose business it is to follow the matter up. The inspection of fuel should be placed in the hands of some person or department. A sufficient force of inspectors should be provided to watch the output of each mine closely. If there is any question as to change in the grade of coal, as concerns its heat value, it may be checked roughly by laboratory calorimeter tests, which are simple and inexpensive.

Under present conditions most roads have no way of detecting whether the proper size screens, or any screens at all, are used at the mines and often a large amount of slate and rock is included, which is not only worthless but interferes greatly with the performance of the locomotive. Another important feature is that the weights should be checked and precautions taken to make sure that the scales at the coal tipples are accurate and in good condition. Another fruitful source of economy is to see that each one of the coal cars is loaded to its capacity, and so loaded that the coal will not be lost off in transit. A complaint was made in a certain district last year, during the time of car shortage, that the mines were short 70 or 80 cars a day. Investigation showed that to each loaded car could be added from one to four tons. A little attention to this matter resulted in a considerable improvement.

Distribution.

On the larger railroad systems, where there are several sources of supply, the problem of buying and distributing the coal to the best advantage is a serious one. Ordinarily this question is not given the thought and attention which it should have, but is decided for reasons which seem important but which do not prove to be the most important ones when the question is given more careful study. An ideal and practical method of controlling the distribution to the different coaling stations was presented by J. G. Crawford, fuel engineer of the C., B. & Q., in the paper which he presented before the November, 1907, meeting of the Western Railway Club. The idea is simple, and is based on good hard, common sense. Certain traffic conditions may arise which will make it necessary, or advisable at times, to temporarily interfere with such a system of distribution and the general plan may have to be modified because of certain traffic conditions; the fuel department should, of course, keep in close touch with the car service and traffic conditions.

Because of the importance of Mr. Crawford's paper and the fact that the system advocated by him is eminently practical as a basis upon which to work, that portion of the paper which refers to the distribution of fuel is reproduced complete. The paper was thoroughly discussed at the meeting and the foot notes, which are used, refer to facts which were brought out in connection with the discussion. The advantages of this system of distribution are the possible reduction in the cost of fuel, the improvement which may be made in locomotive service by supplying a uniform grade of coal over a division and the increased earning capacity of the coal cars. For convenience Mr. Crawford has assumed a hypothetical case—a railroad known as the A. B. C. R. R. System. The first step would be to test the different coals which were available and the following results are assumed to have been obtained:

ITEM	TEST NUMBER				AVERAGE	EXPLANATIONS
1	TRAIN					
2	DATE					
3	ENGINE					
4	ENGINEER					
5	FIREMAN					
6	WEATHER	Rain				
7		Temperature				
8	ACTUAL TIME TABLE		Leave or Arrive			
9			Arrive or Leave			
10	TIME	On road				
11		Of stops				
12		In motion				Item 10 – Item 11
13		Shut off while in motion				
14		Using steam				Item 12 – Item 13
15	NUMBER OF STOPS					
16	" " CARS					
17	AV. SPEED M.P.H.	In motion				÷ Item 12
18		Between terminals				÷ Item 10
19	BOILER PRESSURE WHILE USING STEAM	Average				
20		Minimum				
21	FACTOR OF EVAPORATION, QUALITY ASSUMED 98.5 %					[illegible] (See Kent)
22	COAL	ANALYSIS	Moisture %			
23			Volatile Matter %			
24			Fixed Carbon %			
25			Ash %			
26			Sulphur %			
27			British Thermal Units by Parr Calorimeter			
28		CONSUMPTION ACTUAL	Total			
29			Per hour			Item 28 ÷ Item 14
30			" " per sq. ft. of G. S.			Item 29 ÷ Grate surface
31	WATER	Apparently evaporated				Water entering boiler
32		Equivalent Evaporation, from and at 212°				Item 31 × Item 21
33		Temperature				Thermometer in manhole
34	EVAPORATION	PER POUND OF COAL, ACTUAL	Apparent			Item 31 ÷ Item 28
35			Equivalent			" 32 ÷ " 28
36		RATE PER HR.	APPARENT			" 31 ÷ " 14
37			EQUIVALENT	Total		" 32 ÷ " 14
38				Per sq. ft. H. S. (Inside Flues)		" 37 ÷ Heating surface
39	COMMERCIAL BOILER HORSEPOWER					" 37 ÷ 34.5

17-COLUMNS BETWEEN ARROW POINTS FOR TEST RECORDS

LESS IMPORTANT AVERAGE RESULTS

COAL	CONSUMPTION	TOTAL	Dry	
			Combustible	
		PER HR	Dry	
			Combustible	
EVAPORATION	APPARENT	PER LB. COAL	Dry	
			Combustible	
	EQUIVALENT		Dry	
			Combustible	
			Actual, by Parr Calorimeter	
Heating surface per Boiler H.P.				
Boiler efficiency				

ENGINE DATA

Engine number		
" class		
Heating surface, Inside flues		
Grate "		
Exhaust tip, diameter		
" ", bridge		

HELPER USED

TEST	FROM	TO

KIND OF COAL

Name	
State	
County	
Town	
Mine	
Grade	
Mined by	
Purchased of	
Tested between	

C. B. & Q. R. R. Co.
OFFICE FUEL ENGINEER
COAL TESTS
CHICAGO, ILL.
NO.

FIG. 2.—SUMMARY SHEET FOR RESULTS OF LOCOMOTIVE FUEL TESTS.

Name of Coal.	Equivalent Evaporation per Pound of Coal, Actual.	Rank.	Price per Ton.
A	5.60	80.0%	$1.50
B	5.60	80.0	1.30
C	6.30	90.0	1.30
D	6.30	90.0	1.60
E	7.00	100.0	1.30
F	7.00	100.0	1.10
G	7.70	110.0	1.40
H	7.70	110.0	1.20
I	8.40	120.0	2.10
J	8.40	120.0	2.50

"The above coals do not necessarily represent individual companies or mines, but coals of equal heat value and price from the same point of distribution are included under one name. For convenience the coals have been assumed to be poorer and better than the standard coal by multiples of 10 per cent. The prices selected in most cases bear little or no relation to the heat value, which is true under actual conditions.

Coal Distribution, A. B. C. Railroad.—"For convenience the A. B. C. Railroad System, as shown in Fig. 10, has been assumed as having the following requirements and conditions:

Coaling stations require respectively the equivalent of 100, 200 and 300 tons of standard (100 per cent.) coal per day.

That the railroad can get as much coal as it desires from all the sources of supply.

That all these coals will mix with each other without additional trouble from clinkering, etc.*

Cost of handling at chutes, ten cents † per ton.

Cost of haulage from source of supply to chute, two mills per ton mile.‡ (Under the accounting system put in force by the Interstate Commerce Commission on July 1st no charge is made against the fuel account for the haulage of coal on a company's own line. This has been the practice, at least on the more important lines, for a number of years past; although about 1901 at least two of the important systems charged their fuel account with the haulage of company coal at the rates of three and five mills per ton mile, respectively. Whether or not the haulage of company coal on a company's own line is, or is not, charged to the fuel account, is a matter of no importance, as the cost remains the same in either case, but in order to work out the best coal distribution it is a matter of the utmost importance to know accurately this cost of haulage. The above rate of two mills per ton mile is probably too low in most cases, but is selected at this figure to simplify the computations to follow.

Competitive Points.—"The price and heat values of the coals have been so selected that they illustrate a number of combinations that arise in practice which will be taken up under the following headings:

Equal Heat Value, Unequal Price and Same Source of Supply.—"Coals G and H having the same heat value, and being supplied from the same points should cost the same. As $1.40 per ton is asked for G and $1.20 for H, G should not be used, and thus is eliminated from consideration.

Equal Heat Values, Unequal Price and Different Sources of Supply.—"Coals J and I, Fig. 4, have the same heat value and J is supplied at $2.50 per ton from a station No. 4, 300 miles from station No. 43, where I is supplied at $2.10 per ton. The dividing line between coals J and I, which is called the competitive point, is found from the following equation in which X is the distance from station No. 4 to the competitive point:

$$\frac{\$2.50 + \$\,.10 + x\,(\$.002)}{120\%} = \frac{\$2.10 + \$\,.10 + (300 - x)\,\$.002}{120\%}$$

$$x = 50 \text{ miles}$$

This shows that at all points north of station No. 38, J coal should be used; south of station No. 38, I coal should be used,

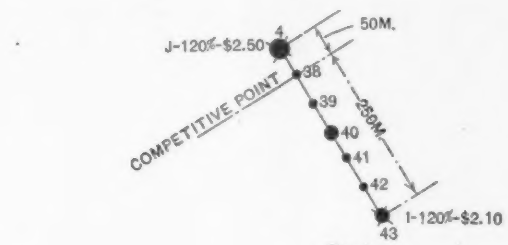


Fig.4

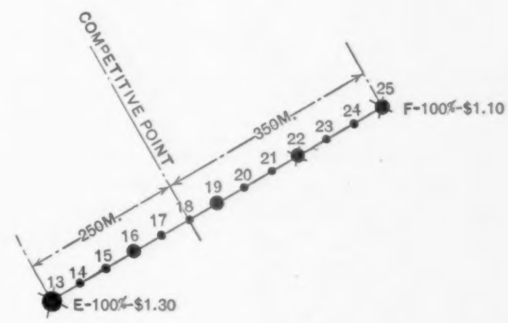


Fig.5

and at station No. 38 either I or J coal can be used, as both will cost $2.70 on the engine at that point, made up as follows:

	Coal J	Coal I
F. O. B. station	No. 4	No. 43
First cost	$2.50	$2.10
Haulage	.10	.50
Handling at chute	.10	.10
Cost on engine per ton	$2.70	$2.70
Cost on engine of amount equivalent to one ton of standard coal	2.25	2.25

"Coals E and F, Fig. 5, have also the same heat value and are from different sources of supply. The equation for finding the competitive point of these coals is as follows:

$$\frac{\$1.30 + \$\,.10 + x\,(\$.002)}{100\%} = \frac{\$1.10 + \$\,.10 + (600 - x)\,\$.002}{100\%}$$

$$x = 250 \text{ miles}$$

"This shows that at station No. 18 both coals cost the same, made up as follows:

	Coal E	Coal F
F. O. B. station	No. 13	No. 25
First cost	$1.30	$1.10
Haulage	.50	.70
Handling	.10	.10
Cost on engine	$1.90	$1.90

Unequal Heat Values, Equal Price, Same Source of Supply.—"Coals B and C costing the same, are supplied from the same source, but B is an 80 per cent. and C a 90 per cent. coal. As C is 12½ per cent. better than B, C should be used and B excluded.

Unequal Heat Values, Unequal Prices, Same Source of Supply.—"Coals A and D are supplied from the same source, but are different in both heat values and price, A being an 80 per cent.

* If the different coals will not mix without clinkering, or if the engine, as drafted for one of them, is not suitable for the other, the distribution should be modified to overcome it. H. T. Bentley, of the Chicago & Northwestern, called attention to a remarkable improvement in the performance of engines on that road due to an arrangement made by the purchasing agent whereby all the principal divisions are now served with either Illinois or Iowa coal entirely. Previous to this change some of the divisions had been served partly with one and partly with the other.

† On the Frisco System we are distributing coal on practically the basis outlined by Mr. Crawford, taking into account first cost, evaporative efficiency, labor of handling at 8 cents per ton and haul at three mills per ton mile. After making this distribution, which is revised from time to time (the efficiency of coals determined by actual locomotive test) we attempt in addition to take into consideration the difference in grade conditions as well as the direction of the prevailing light tonnage movement.—*Eugene McAuliffe.*

‡ There are many traffic conditions which will arise that will tend to make any predetermined coal distribution uneconomical for a short period on account of some haulage rate increasing; on the other hand there will be cases where the traffic conditions will tend to lower the established haulage rate. Thus, the advantage of the fuel department keeping in touch with the car and traffic situations, as mentioned by one of the speakers.—*J. G. Crawford.*

‡ The enormous cost of haulage of company coal is not as a rule fully appreciated. Company material amounts to about 10% of the total traffic of a railroad and the majority of this company material is coal. The importance of keeping the ton mileage of company material, and especially coal, to a minimum is thus seen. This can best be accomplished by knowing what the haulage of company material is costing and the most elaborate method of determining this would necessitate each shipment of company material to be billed at a rate representing the cost of haulage. In the case of coal the above results can be accomplished in a simple manner; thus: Each coaling station can arrange to keep record on a suitable form of a number of tons of each kind of coal used each month. This blank will then be forwarded to headquarters and the cost of haulage and handling inserted. This blank then gives a complete cost of the coal for each coaling station for each month and this cost is subdivided between first cost, haulage and handling. A summary of these blanks and comparison from month to month will soon show where improvement is to be made.—*J. G. Crawford.*

TABLE NO. 1.
A. B. C. RAILROAD COMPANY.
PRESENT COAL DISTRIBUTION AND COST OF COAL PER DAY.

Stations.	Tons Standard Coal Required.	Coal Being Used. Kind.	Tons.	Per Ton Cost.	Haulage. Miles.	Ton-Miles.	Cost of Coal by Stations. First Cost.	Hauling.	Handling.	Total.
1	200	A	250.0	$1.50	0	0	$375.00	$0.00	$25.00	$400.00
2	100	A	125.0	1.50	50	6,250	187.50	12.50	12.50	212.50
3	100	A	125.0	1.50	100	12,500	187.50	15.00	12.50	225.00
4	300	A	375.0	1.50	150	56,250	562.50	112.50	37.50	712.50
5	100	D	111.1	1.60	200	22,220	177.76	44.44	11.11	233.31
6	100	D	111.1	1.60	250	27,775	177 76	55.55	11.11	244.42
7	200	D	222.2	1.60	300	66,660	355.52	133.32	22.22	511.06
8	100	D	111.1	1.60	350	38,885	177.76	77.77	11.11	266.64
9	100	D	111.1	1.60	400	44,440	177.76	88.88	11.11	277.75
10	200	D	222.2	1.60	450	99,990	355.52	199.98	22.22	577.72
38	100	I	88.3	2.10	250	20,825	174.93	41.65	8.33	224.91
39	100	I	83.3	2.10	200	16,660	174.93	33.32	8.33	216.58
40	200	I	166.6	2.10	150	24,990	349.86	49.98	16.66	416.50
41	100	I	83.3	2.10	100	8,330	174.93	16.66	8.33	199.92
42	100	I	83.3	2.10	50	4,165	174.93	8.33	8.33	191.59
43	200	I	166.6	2.10	0	0	349.86	.00	16.66	366.52
11	100	E	100.0	1.30	100	10,000	130.00	20.00	10.00	160.00
12	100	E	100.0	1.30	50	5,000	130.60	10.00	10.00	150.00
13	300	E	300.0	1.30	0	0	390.00	.00	30.00	420.00
26	100	E	100.0	1.30	50	5,000	130.00	10.00	10.00	150.00
27	100	E	100.0	1.30	100	10,000	130.00	20.00	10.00	160.00
14	100	C	111.1	1.30	400	44,440	144.43	88.88	11.11	244.42
15	100	C	111.1	1.30	350	38,885	144.43	77.77	11.11	233.31
16	200	C	222.2	1.30	300	66,660	288.86	133.32	22.22	444.40
17	100	C	111.1	1.30	250	27,775	144.43	55.55	11.11	211.09
18	100	B	125.0	1.30	200	25,000	162.50	50.00	12.50	225.00
19	200	B	250.0	1.30	150	37,500	325.00	75.00	25.00	425.00
20	100	B	125.0	1.30	100	12,500	162.50	25.00	12.50	200.00
21	100	F	100.0	1.10	200	20,000	110.00	40.00	10.00	160.00
22	200	F	200.0	1.10	150	30,000	220.00	60.00	20.00	300.00
23	100	F	100.0	1.10	100	10,000	110.00	20.00	10.00	140.00
24	100	F	100.0	1.10	50	5,000	110.00	10.00	10.00	130.00
25	200	F	200.0	1.10	0	0	220.00	.00	20.00	240.00
28	200	G	181.8	1.40	450	81,810	254.52	163.62	18.18	436.32
29	100	G	90.9	1.40	400	36,360	127.26	72.72	9.09	209.07
30	100	G	90.9	1.40	350	31,815	127.26	63.63	9.09	199.98
31	200	G	181.8	1.40	300	54,540	254.52	109.08	18.18	381.78
32	100	G	90.9	1.40	250	22,725	127.26	45.45	9.09	181.80
33	100	H	90.9	1.20	200	18,180	109.08	36.36	9.09	154.53
34	200	H	181.8	1.20	150	27,270	218.16	54.54	18.18	290.88
35	100	H	90.9	1.20	100	9,090	109.08	18.18	9.09	136.35
36	100	H	90.9	1.20	50	4,545	109.08	9.09	9.09	127.26
37	200	H	181.8	1.20	0	0	218.16	.00	18.18	236.34
Total....	6,000		6,158.3			1,084,035	$8,840.55	$2.168.07	$615.83	$11,624.45
Average				$1.44	176		1.44	.35	.10	1.89

coal costing $1.50 per ton, and D a 90 per cent. coal costing $1.60 per ton. D being 12½ per cent. better than A and costing only 6⅔ per cent. more, should be used to the exclusion of A.

Unequal Heat Values, Unequal Prices and Different Sources of Supply.—"Coals D and J, Fig. 6, are unequal in heat value and price and are supplied from different points. Their competitive point would be found as follows:

$$\frac{\$2.50 + \$.10 + x\ (\$.002)}{120\%} = \frac{\$1.60 + \$.10 + (150 - x)\ \$.002}{90\%}$$

$$x = 14.3 \text{ miles}$$

"The competitive point of coals D and J is therefore fourteen miles north of station No. 4; chutes at stations No. 1, No. 2 and

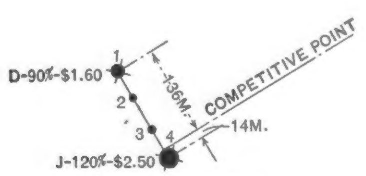


Fig.6

No. 3 should be supplied with D and station No. 4 with J. At the competitive point coal on the engine would cost as follows:

	Coal D	Coal J
F. O. B. stations	No. 1	No. 4
First cost	$1.60	$2.50
Haulage	.27	.03
Handling	.10	.10
Cost on engine per ton	$1.97	$2.63
Cost on engine of amount equivalent to one ton standard coal	2.19	2.19

"The competitive point of coals J and E, Fig. 7, is found from the following equation:

$$\frac{\$2.50 + \$.10 + x\ (\$.002)}{120\%} = \frac{\$1.30 + \$.10 + (450 - x)\ \$.002}{100\%}$$

$$x = 36.4 \text{ miles}$$

"This shows that J coal cannot be used east of station No. 4 and that E coal should be used at stations No. 5 to No. 13 inclusive. At the competitive point coal on the engine would cost as follows:

	Coal J	Coal E
F. O. B. station	No. 4	No. 13
First cost	$2.50	$1.30
Haulage	.07	.83
Handling	.10	.10
Cost on engine per ton	$2.67	$2.23
Cost on engine of amount equivalent to one ton standard coal	2.23	2.23

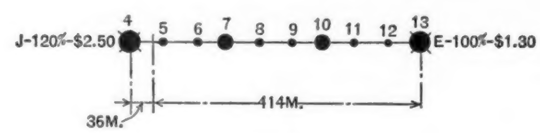


Fig 7

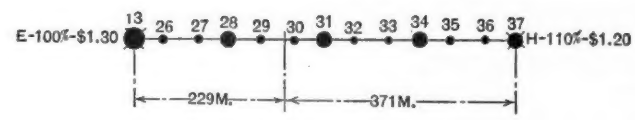


Fig.8

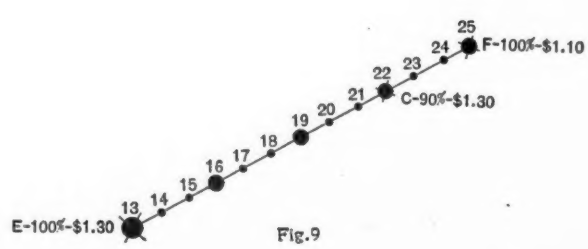


Fig.9

The competitive point of coals E and H is determined by the following equation, as shown in Fig. 8:

$$\frac{\$1.30 + \$.10 + (\$.002)}{100\%} = \frac{\$1.20 + \$.10 + (600 - x)\ \$.002}{110\%}$$

$$x = 229 \text{ miles}$$

"E coal is thus limited to station No. 29 and west thereof, and

TABLE NO. 2.

A. B. C. RAILROAD COMPANY.

PROPOSED COAL DISTRIBUTION AND COST OF COAL PER DAY.

		Coal to Be Used.			Haulage.		Cost of Coal by Stations.			
Stations.	Tons Standard Coal Required.	Kind.	Tons.	Per Ton Cost.	Miles.	Ton-Miles.	First Cost.	Hauling.	Handling.	Total.
1	200	D	222.2	$1.60	0	0	$355.52	$0.00	$22.22	$377.74
2	100	D	111.1	1.60	50	5,555	177.76	11.11	11.11	199.98
3	100	D	111.1	1.60	100	11,110	177.76	22.22	11.11	211.09
4	300	J	250.0	2.50	0	0	625.00	.00	25.00	650.00
38	100	J	83.3	2.50	50	4,165	208.25	8.33	8.33	224.91
39	100	I	83.3	2.10	200	16,660	174.93	33.32	8.33	216.58
40	200	I	166.6	2.10	150	24,990	349.86	49.98	16.66	416.50
41	100	I	83.3	2.10	100	8.330	174.93	16.66	8.33	199.92
42	100	I	83.3	2.10	50	4,165	174.93	8.33	8.33	191.59
43	200	I	166.6	2.10	0	0	349.86	.00	16.66	366.52
5	100	E	100.0	1.30	400	40,000	130.00	80.00	10.00	220.00
6	100	E	100.0	1.30	350	35,006	130.00	70.00	10.00	210.00
7	200	E	200.0	1.30	300	60,000	260,00	120.00	20.00	400.00
8	100	E	100.0	1.30	250	25,000	130.00	50.00	10.00	190.00
9	100	E	100.0	1.30	200	20,000	130.00	40.00	10.00	180.00
10	200	E	200.0	1.30	150	30,000	260.00	60.00	20.00	340.00
11	100	E	100.0	1.30	100	10,000	130.00	20.00	10.00	160.00
12	100	E	100.0	1.30	50	5,000	130.00	10.00	10.00	150.00
13	300	E	300.0	1.30	0	0	390.00	.00	30.00	420.00
14	100	E	100.0	1.30	50	5,000	130.00	10.00	10.00	150.00
15	100	E	100.0	1.30	100	10,000	130.00	20.00	10.00	160.00
16	200	E	200.0	1.30	150	30,000	260.00	60.00	20.00	340.00
17	100	E	100.0	1.30	200	20,000	130.00	40.00	10.00	180.00
26	100	E	100.0	1.30	50	5,000	130.00	10.00	10.00	150.00
27	100	E	100.0	1.30	100	10,000	130.00	20.00	10.00	160.00
28	200	E	200.0	1.30	150	30,000	260.00	60.00	20.00	340.00
29	100	E	100.0	1.30	200	20,000	130.00	40.00	10.00	180.00
18	100	F	100.0	1.10	350	35,000	110.00	70.00	10.00	190.00
19	200	F	200.0	1.10	300	60,000	220.00	120.00	20.00	360.00
20	100	F	100.0	1.10	250	25,000	110.00	50.00	10.00	170.00
21	100	F	100.0	1.10	200	20,000	110.00	40.00	10.00	160.00
22	200	F	200.0	1.10	150	30,000	220.00	60.00	20.00	300.00
23	100	F	100.0	1.10	100	10,000	110.00	20.00	10.00	140.00
24	100	F	100.0	1.10	50	5,000	110.00	10.00	10.00	130.00
25	200	F	200.0	1.10	0	0	110.00	.00	20.00	130.00
30	100	H	90.9	1.20	350	31,815	109.08	63.63	9.09	181.80
31	200	H	181.8	1.20	300	54,540	218.16	109.08	18.18	345.42
32	100	H	90.9	1.20	250	22,725	109.08	45.45	9.09	163.62
33	100	H	90.9	1.20	200	18,180	109.08	36.36	9.09	154.53
34	200	H	181.8	1.20	150	27,270	218.16	54.54	18.18	290.88
35	100	H	90.9	1.20	100	9,090	109.08	18.18	9.09	136.35
36	100	H	90.9	1.20	50	4,545	109.08	9.09	9.09	127.26
37	200	H	181.8	1.20	0	0	218.16	.00	18.18	236.34
Total	6,000		5,760.7			783,140	$8,058.68	$1,566.28	$576.07	$10,201.03
Average				$1.40	136		1.40	.27	.10	1.77

NOTE—At station 38 either J or I coal could be used with equal cost and J has been assumed as the coal to be used. Similarly with station No. 18 F coal has been assumed whereas E might be used.

H coal from stations No. 30 to No. 37 inclusive. At the competitive point the following would be the cost of coal on the engine:

	Coal E	Coal H
F. O. B. station	No. 13	No. 37
First cost	$1.30	$1.20
Haulage	.46	.74
Handling	.10	.10
Cost on engine per ton	$1.86	$2.04
Cost on engine of amount equivalent to one ton standard coal	1.86	1.86

"The competitive point of coals C and F, Fig. 9, is found from the following equation:

$$\frac{\$1.30 + \$\ .10 + x\ (\$.002)}{90\%} = \frac{\$1.10 + \$\ .10 + (150 - x)\ \$.002}{100\%}$$

$$x = -\ 13.2 \text{ miles}$$

"Note that x is a negative quantity which shows that F can be hauled 26.4 miles more than the above 150 miles and then cost the same on the engine at station No. 22, the point of distribution of C, as the amount of C coal equivalent to one ton of standard coal. This is proven by the following table:

	Coal C	Coal F
F. O. B. station	No. 22	No. 25
First cost	$1.30	$1.10
Haulage	.00	.30
Handling	.10	.10
Cost on engine	$1.40	$1.50
Cost on engine of amount equivalent to one ton standard coal	1.55	1.50

Present vs. Proposed Coal Distribution, A. B. C. R. R.—"The present coal distribution on the A. B. C. Railroad is shown by Fig. 10 and the proposed distribution by Fig. 11. Some objection may be offered to the distribution shown in Fig 10, but when it is considered that the relative heat values are not known before tests have been made the distribution is not an improbable one.

"The cost of fuel per day under the present system of coal distribution is shown in Table 1, and that of the proposed distribution by Table 2. The following totals, Table 3, made up from Tables 1 and 2, show the amount of each kind of coal used under the present and proposed distributions:

TABLE 3.

	Present Distribution.		Proposed Distribution.	
Kind of Coal.	Tons Used.	Equivalent to Following Tons of Standard Coal.	Tons Used.	Equivalent to Following Tons of Standard Coal.
A	875.0	700	.0	0
B	500.0	400	.0	0
C	555.5	500	.0	0
D	888.8	800	444.4	400
E	700.0	700	2300.0	2300
F	700.0	700	1100.0	1100
G	636.3	700	.0	0
H	636.3	700	999.9	1100
I	666.4	800	583.1	700
J	.0	0	333.3	400
Total	6158.3	6000	5760.7	6000

"The following table shows the averages and totals of Tables 1 and 2, and shows the savings to be made by adopting the proposed distribution:

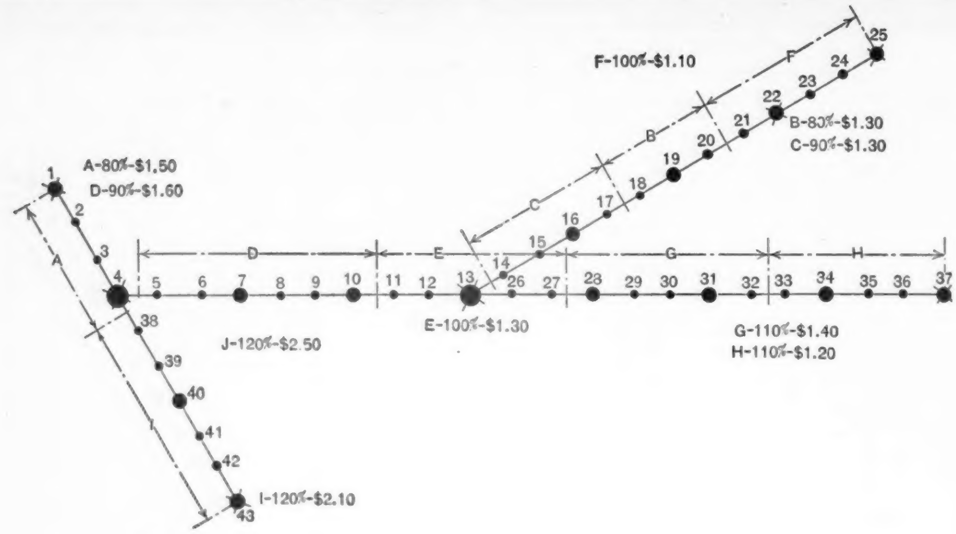
TABLE 4.

COAL		AVERAGE		COST OF COAL			
Distribution	Tons	Haulage	Ton Miles	First Cost	Haulage	Handling	Total
Present	6158.3	176	1,084,035	$8840.55	$2168.07	$615.83	$11,624.45
Proposed	5760.7	136	783,140	8058.68	1566.28	576.07	10,201.03
Difference	397.6	40	300,895	$781.87	$601.79	$39.76	$1,423.42

"The proposed coal distribution would effect a daily saving of $1,423.42 on a daily expenditure of $11,624.45, or a saving of 12.2 per cent.; $782 of the saving is due to the decreased amount paid mine companies; $602 due to saving in haulage and $40 is saved by having less tons of coal to handle, there being only 5,761 tons of coal used daily under the proposed distribution, as against 6,158 tons under the present distribution. The table also shows the decrease in the average length of haul and the decrease in total ton miles.

"It is not expected that every railroad company in working out a coal distribution would find that there could be a saving of over 12 per cent. made by distributing the coal according to the methods herein outlined, but there is no doubt but what considerable saving is to be effected on most systems.

"It is not expected that any railroad can at all times distribute coal according to some predetermined plan, but the cost of fuel will be considerably less, when purchased and distributed ac-



NOTE

● Denotes coaling station using the equivalent of 100 tons standard coal per day.
● Denotes coaling station and division point using the equivalent of 200 tons standard coal per day.
● Denotes coaling station and division point using the equivalent of 300 tons standard coal per day.
X Denotes source of coal supply.
Distance between coaling stations, 50 miles.
Distance between division points, 150 miles.
Numbers indicate name of coaling stations.
Letters denote name of coal.
A-80%-$1.50, shows that coal "A" having a heat value of 80% of the standard coal is supplied at $1.50 per ton F. O. B. cars.

FIG. 10.—PRESENT COAL DISTRIBUTION ON A. B. C. R. R.

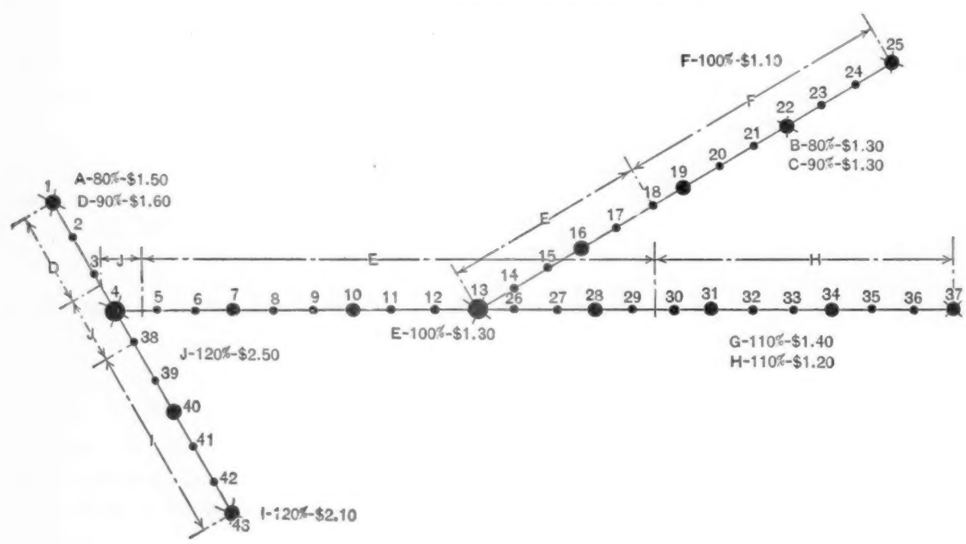


FIG. 11.—PROPOSED COAL DISTRIBUTION ON A. B. C. R. R.

cording to its heat value and cost, than though purchased and distributed in a semi-haphazard manner.

"The greatest saving can probably be effected when the commercial demand is not at a maximum, which will prove beneficial to purchase and distribution by allowing more economical coals to be used and correspondingly less amounts of the less economical coals."

Types of Locomotive Coaling Stations and Cost of Handling Coal.

The best discussion of the utility of the various types of locomotive coaling stations in use is to be found in the reports made by the "Committee on Buildings" of the American Railway Engineering and Maintenance of Way Association at the 1907 and 1908 conventions. The parts of these reports which refer to coaling stations are quite completely reproduced in this section.

The cost of handling the coal at the coaling stations, as ordinarily compiled by the railroads, includes only the cost of operation and sometimes of maintenance. Interest and depreciation and the cost of storage in cars are entirely neglected, and the comparison of the results gained on one road with those on another, or even between two divisions on the same road, is useless. They are worse than useless for comparing the economy of different types of plants. The committee has emphasized this point and submitted recommendations as to what should be included in these costs. The accompanying table of costs of different types of stations has been tabulated from information presented in the report of the 1907 committee. In lieu of exact information the committee has estimated certain items in order to make the costs roughly comparable, but the information cannot, of course, be considered as exact; the number of stations considered is comparatively small and the conditions under which they are operated are not given, so that this information should be used in a general way only.

The report of the 1907 committee is as follows:

"*A locomotive coaling plant should minimize: Delays to engines while coaling; delays to coal cars; the cost of handling coal; sometimes it is also desired to accurately measure the coal as delivered to locomotives.*

"An ample storage capacity insures against delays, due to interruption of coal supply, to bunching of engines and to breakdowns, derailments and necessary repairs. At important points, it is sometimes desirable to provide duplicate machinery.

The roundhouse track arrangement should be as compact as possible and at the same time allow the necessary free movement. The question of the proper location of the coaling plant with reference to the cinder pit depends upon the type of plant adopted. In cold weather, delay to the engine after the fire is cleaned is liable to cause leaking, though some of the trouble attributed to this cause is probably due to an unwise use of the injector. Some handle cinders with the machinery for handling coal. This practice is, however, not recommended.

"The importance of providing storage room so as to cut down the delay of cars as much as possible is ordinarily underestimated. One day's storage in cars of locomotive coal for the Pennsylvania System costs more than $300,000 a year, figuring that the cars are worth only one dollar a day each. An expenditure of $4,000,000 would be justified to avoid holding two days' supply of coal in cars, considering that the structure costs 15 per cent. of the original cost for interest, depreciation and maintenance.

"Figuring 40 tons to the car, storage in cars costs 2½ cents per ton per day, and an expense of $61 a ton is justifiable to avoid it. Ordinarily, storage in the bin is much cheaper than in cars, yet the usual practice is to keep from one to five days' supply stored in cars at the different plants.

"Theoretically, a coaling plant should be designed to take care of all the coal to be held for emergencies, so that cars can be released promptly upon arrival. This is, of course, not always feasible.

"All plants for self-clearing cars should have the hoppers wide enough so that the coal can be shoveled from flat bottom cars by hand, if desired, and so that side dump cars can be used.

TYPE—SEE SECTIONS IN ARTICLE	A	B		C	D	E				F			G	I			J					K		
TYPE OF COALING STATION.	COAL SHOVELED FROM CAR TO TENDER.			Coal shoveled into small dump cars	TRESTLE TYPE—CARS PLACED BY LOCOMOTIVE.					TRESTLE TYPE—POWER OPERATED			LOCOMOTIVE CRANE.	BALANCED TWO-BUCKET TYPE.			LINK BELT.					ROBBINS BELT TYPE.		
		Jib crane	Jib crane																					
No stations considered	1	1	1	4	5	6	2	17	1	1	5	55	3	6	1	1	1	1	3	4	1††	4	1	1
Av. No. tons handled per day (all stat'ns)				235	133	305	370	444			166		195	247					147	345		280		
" " " " " " each "	157	12	13	59	26	51	175	26	67	264	33	82	65	41	113	50	165		49	86	450		127	218
Interest and depreciation—per ton	$.002	.014	.017	.008	.010*	.005	.012*	.008*	.023	.017	.027	.027	.015	.019	.022	.038	.037*	.020	.025	.018	.116	.017	.032	.033
Operation—per ton	$.104	.123	.206	.103	.113	.031	.061	.036	.028	.035	.051	.070	.039	.045	.035	.087	.027	.049	.037	.024	.028	.027	.043	.031
Maintenance—per ton	$.001	.020*	.022	.005	.005*	.005	.006*	.004*	.001	.008*	.013*	.009	.005	.005	.005*	.005	.010*	.016	.010*	.005	.021	.005	.006	.005
Car Storage—per ton	$.066	.075	.075	.062	.047	.050*	.043	.050*	.050*	.056*	.000	.037	.075	.043*	.020	.025	.044	.058	.041	.047	.019	.044	.041	.000
Total cost—per ton	$.173	.232	.320	.178	.175	.091	.122	.098	.102	.116	.091	.143	.134	.112	.082	.155	.118	.143	.113	.094	.184	.093	.122	.069
Time covered by above figures (months)						10	1	1	9	3		1	24	10	3	1	6	60	1		3	10	12	3
% Self clearing cars	0	0	0	0	0	90		100	75		‡	67	0	63		66				80		90		

* Estimated. ‡ Large proportion self-clearing. †† Special construction and with scales.

"In this statement, the figures which are not available have been estimated. In order to make a fair comparison, we have assumed that it is desirable to hold at the plant, either in cars or on the ground, a total of three days' supply. The figures presented are of value in a general way only. We have used ten per cent. of the original cost for interest and depreciation for all plants, independent of the character of construction. Considering the present rate of development, the necessary changes in terminals, etc., this is believed to be none too high. A good many of the plants reported have not been in operation long enough and the length of time over which the costs extend is too short, in most cases, to make the maintenance figures reliable. The lack of uniformity in the collection of the statistics and the varying conditions under which they were prepared, make any close comparisons of little value. They indicate how much a slight variation in the conditions, not generally considered, can affect the cost. In considering this question, it should be remembered that a saving of dollars per year for the railroad, and not cents per ton for the individual plant, is the result to be aimed at."

COMPILED FROM DATA IN THE REPORT OF THE COMMITTEE ON BUILDINGS AT THE 1907 CONVENTION OF THE AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION.

"Self-clearing cars can be unloaded into a hopper for at least six cents a ton less than the cost of unloading flat bottom cars by hand. Using 15 per cent. per annum of the original cost as the cost of the plant, an expense of $146 is justified to save handling one ton a day by hand.

DESCRIPTION OF PLANTS.

A.

"Where the quantity of coal handled is small and especially at terminal points where the engines lie over night and the coaling can be done by the hostler or watchman, coaling direct from the cars is the cheapest. This work can be aided by elevating the track, on which the coal cars stand, from two to four feet above the locomotive track.

Shoveling from the coal car direct into the locomotive has the advantage that it delivers the coal in the best possible condition. Crushing, due to handling, is kept at a minimum and large lumps can be broken up ready for the fire by the shoveler. The tendency of large bins to separate the slack from the lump is avoided.

B.

Coaling from Cars with a Jib Crane.—"Where the engines are needed as soon as they can be cared for, where they come bunched, or where the hostlers cannot do all the coaling in connection with their other work at the time desired, it is recommended that there be, in addition to the elevated track, an elevated platform with buckets of about one ton capacity into which coal can be shoveled at different times, these buckets to be raised by a jib crane which can be operated by hand or by air from the engine, and to be emptied when the engines come too fast for the men to take care of them. By this method the cost can be kept down to almost that of coaling direct from the cars into the engines. These buckets can be used for emergency coaling stations en route where coal is only occasionally required.

C.

"By having, instead of buckets, small dump cars on an elevated platform and the coal car track elevated considerably above the track on which the locomotive stands, more engines can be coaled quickly.

D.

Williams-White Type.—"By still further increasing the elevation, the shoveling can be done directly into bins, by which the amount stored can be increased and a larger number of engines accommodated promptly. These bins can be filled with different amounts of coal, so that, by selecting the bin, the amount needed can be obtained. With all of the designs, thus far considered, flat-bottom cars are practically necessary.

E.

Trestle Type.—"The next step is the construction of the high trestle with the coal car track on top of the storage bins, thirty or forty feet above the engine track. The cost of switching is increased, but by the use of self-clearing cars the cost of delivering coal from the cars to the bin can be almost entirely eliminated. The maximum grade of the approach desirable is usually considered as five per cent. Where the coal is not shoveled, this type of plant keeps the breakage of the coal at a minimum of all plants where the coal is not shoveled by hand. In considering the expense of operating these plants, the cost of placing the cars on the trestle by a locomotive, an expensive and dangerous operation, is not ordinarily included.

F.

Power-Operated Trestle Type.—"Instead of using a locomotive to place the cars, these plants can be equipped with a hoisting engine, allowing the use of a twenty per cent. grade. The machinery costs less than the trestle approach, much ground space can be saved and the operation is cheaper and safer when the cost of switching is considered. This type ordinarily increases the possibilities of providing storage room and does away with a considerable liability to accident.

"Where two or more tracks are to be served and the necessary room is available, the coal car track can be put at right angles to the locomotive tracks. In some cases, where it is desired to coal on four tracks or on two main tracks, duplicate plants are constructed.

"The trestle types are handicapped by the fact that the structure must sustain heavily loaded cars and also either locomotives or have power available to raise the cars. The costs per ton for maintenance are higher than is generally assumed, and if a fireproof structure is built, it would be expensive. They ordinarily

cannot be placed in the most desirable location, and are not available in many cases where the room is cramped.

G.

Locomotive Crane Type.—"At terminals, where the demands are not too great, coaling can be done by means of a locomotive crane handling the coal direct from flat-bottom cars to a locomotive. This crane can also help switch coal cars, if necessary, and can handle cinders and sand. To allow the use of drop bottom cars, a pit can be constructed from which the crane can handle the coal. To avoid delay to locomotives, a trestle can be constructed on which the crane can work, so that it can load direct into bins, in which a fair amount of storage room can be provided. The bins are not protected from the weather, and the coal and gates are liable to be frozen up.

"With the necessary tracks, the pit and the hoppers, it will be found that this sort of a plant has a considerable first cost. Its cost of operation depends upon the work which can be provided for the crane at spare times. Its value is great in emergency situations and at points where, because of impending changes, the construction of a permanent plant is unwise.

"At a large terminal, where a conveyor plant is used, a locomotive crane would be very valuable to handle cinders and sand and also coal during a possible breakdown of the conveyor. The practical limit of a locomotive crane is said to be about 70 engines a day. The fact that it can unload direct from flat-bottom cars is much in its favor.

H.

Clam-Shell Bucket and Trolley Type.—"A type of plant using a special bucket of the clam-shell type operated on a trolley has been suggested. This can handle coal direct from a pit or from flat-bottom cars into bins over the tracks, and can also handle cinders. While this device has not yet been tried for coaling locomotives, it is receiving more or less attention and will undoubtedly be tested soon. The number of tracks it can serve is unlimited, and the mechanism is simple. The horse-power required is small and the first cost is not excessive. This type would be especially valuable where self-clearing cars cannot be regularly obtained and where large storage is desired. It is believed that with a plant of this type, coal can be handled from flat-bottom cars at a reasonable cost. There should be no difficulty in getting an actual working capacity of seventy-five tons an hour, which is ordinarily ample.

I.

Balanced Two-Bucket Hoist.—"When the space is more or less limited and the amount of coal to be handled and stored is not too great and deep foundations can be constructed, the coal can be lifted into bins by means of two large buckets, operating opposite each other, so that when one is lowered, the other is raised. The coal is delivered into the buckets by gravity from the bottom of a pit under the coal car track through a gate worked by the operator of the bucket. The bucket is automatically dumped into the bins at the top. It requires the continuous attention of a man operating it, but is an efficient machine where the requirements are not too great. The storage room in the bins is limited by the fact that this plant has practically but one point of delivery into the bin.

J.

Link-Belt Type.—"The bucket conveyor or link-belt type requires a small ground space, has great flexibility of adjustment to suit different conditions, and can be used for almost any situation desired. With the softer grades of bituminous coal, such as that from the Indiana fields, these plants tend to break up the coal. Many of these plants are in operation, and, where well cared for, are giving excellent service. The expense of power and repairs are not great, and, where the conditions are such as to recommend their construction, they give good service at a reasonable cost.

K.

Robbins Belt Type.—"Plants raising the coal on a continuous belt of rubber and cotton on an incline of about thirty degrees are coming into use. The maintenance cost is reasonable, and in most situations it can be as readily fitted in as any other type. In some locations, where ample space is available, a better storage yard for coal cars can be provided with this than by any other type, as the receiving hopper can be placed at a considerable distance from the storage bins in any direction. There are very few parts of this which can get out of order. The ordinary objection to this type is the expense of belt renewal, but this is only about 0.2 of a cent per ton, a comparatively small amount, which makes no appreciable difference in the total cost of maintenance.

General Information.

"For large plants, where coal is delivered in self-clearing cars and an unloading hopper is used, tracks can be so arranged that cars can be handled by gravity, without the need of switch engines, decreasing the cost of operation.

"A locomotive crane as an auxiliary for handling cinders, sand and coal in emergencies, is very desirable.

"Although most roads do not now consider it necessary to weigh the coal accurately as delivered to locomotives, some plants are built with this provision. Storage bins, holding as much as one hundred tons, on scales, are used, or else auxiliary bins on scales, with a capacity of five or ten tons, are placed underneath the large storage bins. The use of scales is sometimes avoided with trestle plants by providing small auxiliary pockets in which the measuring can be done by volume. The scales add considerably to the cost.

"With belt or bucket conveyors, the bins should be designed so as to prevent an accumulation of slack. Slack coal in considerable masses, which is not moved for a long time, may cause spontaneous combustion. If it collects, it will finally slide out in large masses, so that one engine may be furnished with a very considerable amount of it, in which cases the performance of trains is seriously interfered with. This trouble can be prevented by designing the bins with hopper bottoms and by placing the points of delivery into the bins directly over the points from which the coal is taken. The slack is then used as it is delivered. If this is not done, the slack will drop directly from the points of delivery, and large lumps will roll to the mouth of the chutes.

"With some grades of coal, where run of mine or lump is used, it is necessary to provide means of breaking it up. Breaker bars can be either placed over the hopper, which will not allow any coal above a certain size to pass without being broken up, or else a crusher can be provided. The breaker bars deliver the coal in better condition, but are more expensive in operation.

"Where softer grades of coal are used, it is important that the plant be designed to avoid breakage as much as possible.

"The handling of sand and cinders is frequently attempted in connection with coaling stations, but, unless separate machinery is provided, they have not generally been successfully operated, due largely to the excessive wear caused by the cinders and sand on the moving parts.

"Some efficient method of fire protection is very desirable, many expensive plants having been destroyed by fire.

"The recent and prospective increases in the cost of labor and timber and the demand for greater reliability of service tend to increase the desirability of having better coaling plants built of steel or reinforced concrete."

Conclusions as Amended After Discussion.

(1) *The cost items should include charges for interest and depreciation, charges for maintenance and operation (the cost of switching cars onto trestles should be included), and a charge for the use of cars for storage purposes.*

(2) *Provision should be made for fire protection, the avoidance of damage to the coal, and its delivery in the best possible condition.*

(3) *The use of self-clearing cars should be made possible, and ordinarily it should be possible to shovel from flat-bottomed cars.*

(4) *Storage for emergency purposes and fireproof construc-*

tion are, in general, to be recommended, and in some cases duplicate machinery is desirable.

Recommendation of 1908 Committee.

An abstract of the report on the "Best Types of Locomotive Coaling Stations for Various Conditions," as presented by the Committee on Buildings at the recent meeting of the American Railway Engineering and Maintenance of Way Association, is as follows:

"Your committee desires, however, at this time to emphasize the need of adequate fire protection at all coaling stations and to call attention to the possibilities of reinforced concrete construction of coaling stations and storage bins, which has been used in some instances, as a method of reducing fire risk, and at the same time securing structures of greater permanency than those ordinarily in use.

"The average insurance rates for open trestle timber construction coaling stations and reinforced concrete fireproof structures are, respectively, one per cent. and one-fourth of one per cent. This would mean that from the standpoint of fire insurance alone we would be justified in expending fifteen per cent. more for a reinforced concrete structure than for a timber coaling station. As the relative cost of the fireproof style of structure at present is about fifty per cent. above that of the heavy timber station, an expenditure of the extra twenty-five per cent. may, perhaps, be justified on the ground that the smaller chance of incidental losses due to interruption of traffic will warrant this additional expense.

"To the 'general information' in last year's report should be added that the 'Balanced Two-Bucket Type' of coal elevator is now built with auxiliary horizontal conveyors, which receive the coal from the elevator buckets and distribute it to bins and pockets, thus adapting it to use in larger coaling stations and storage plants than are practicable for the simple balanced bucket type of coaling station.

"In presenting the following conclusions your committee has been guided by the apparent practicability and adaptability of the various devices rather than by the available statistics regarding comparative costs of handling coal, which are, as has been stated, somewhat unreliable, and consequently not worthy to be accepted as the sole basis for comparison."

The following conclusions are an addition to those adopted at the meeting of 1907:

Conclusions of 1908 Committee as Amended.

(5) *"It is not possible to give absolute limits between which different types of coaling arrangements are to be used. Each installation must be considered as an individual problem. Prices of materials, cost and character of labor, the possible track arrangements, the amount of storage desired, the power and attendance, and shifting service available, all are to be considered.*

(6) *"Where the quantity of coal handled is small, particularly at terminal points where locomotives lie over night, it is recommended that the locomotives be coaled, either directly from cars or by handling from cars to a platform provided with a jib crane and one-ton buckets, and from these buckets to the locomotive.*

(7) *"At terminals, under certain conditions, a locomotive crane, with suitable bucket, is desirable, particularly where other work can be economically performed by the crane."*

(8) *"At terminals where the requirements do not exceed 300 tons a day, when the desired storage is not so great that auxiliary buckets are necessary and where a deep foundation is practicable, a 2-bucket hoist is recommended."*

(9) *"For terminals larger than those previously considered, the type of coaling station which should be selected as most desirable is dependent entirely upon local conditions. Where it is required that coal be delivered to not more than two tracks and where the necessary ground space is available, a coaling station of the 'trestle type,' with incline approach, is recommended. In yards where delivering locomotives are constantly available a plant with a five per cent. incline is preferable to one with a twenty per cent. grade operated by a hoisting engine. Where it is required to deliver coal to more than two tracks, or where the ground space for a 'trestle type' is not available, a 'mechanical conveyor type' is recommended."*

Weighing Coal Issued to Locomotives.

There are several methods by which the coal delivered to the locomotive tenders may be measured with more or less accuracy. Unfortunately most roads have several types of coaling stations, built from time to time, some of which measure or weigh the coal issued, while others do not.

Unquestionably the greatest gains which may be made in fuel economy are in its use on the locomotive. The enginemen, however, cannot be watched closely and spurred on to better efforts unless a careful check is kept on the coal consumption and on those things which effect it. This cannot be done unless some means is provided for measuring the coal issued to each engine with a fair degree of accuracy.

Under proper supervision there seems to be little question but what the average fireman could save one scoopful of coal in every ten. Would this not many times over warrant the installation of weighing or measuring devices on your road, also the establishing of a system of simple daily fuel performance reports, such as is described in another section of this article?

The simplest method of measuring the coal is the use of the jib crane and bucket system, or where "buggies" are used. The average weight of coal which one of these buckets or buggies will hold can easily be determined and care can be taken to see that they are loaded uniformly each time. As a large percentage of existing coaling stations are of the above types the practice on the Nashville, Chattanooga & St. Louis Railway, under the direction of Geo. M. Carpenter, fuel inspector, may be of interest.

Two standard sizes of buggies, holding two and three tons of run of mine coal each, are in use. It is the duty of the foremen at each chute to see that these are filled to capacity and a report is made to the fuel inspector each day as to the initial and number of the car from which each buggy is loaded and the number of the engine to which it is delivered. The fuel inspector can therefore check the weight of each car as against the mine weights, can easily find what kind of coal was used on any engine, and in case of poor coal can at once take the matter up with the inspector at the mine from which the coal was shipped.

The tanks on all the engines are graduated for each ton, the graduation being stenciled on the leg of the tank. This was done by weighing into a buggy one ton of coal, dropping it into the tender, leveling it off to a uniform depth and making a mark on the leg. This was repeated for each ton until the tank was filled level full. When an engine arrives at the roundhouse, at the end of a run, a man shovels the coal down from the sides and back of the tank, levels it up and marks on a coal ticket the "pounds on arrival." To this is added the amount of coal taken. It is thus possible to determine with a close degree of accuracy the amount of coal used on each trip, and with very little extra expense.

Another of the older types of coaling stations which allows the coal to be measured is the low trestle type with different size pockets into which the coal is shoveled from the cars. This type of station does not permit the use of self-clearing cars, and is becoming obsolete, but where it is in use the coal can be measured quite accurately if the pockets are properly calibrated.

With the large overhead storage pockets the problem becomes a more difficult one. The scheme has been tried of suspending the entire pocket and introducing a weighing dynamometer but it is of course necessary to have the pocket hang plumb in order to get accurate results; a wind or an eccentric loading interferes with this.

An arrangement which is being used successfully by several roads is to have an auxiliary pocket underneath the storage pocket. A simple scale arrangement is used for weighing this auxiliary pocket. Accurate results are attained and it is said to be inexpensive to maintain.

In the December, 1904, issue of this journal, page 65, coaling stations on the Baltimore & Ohio Railroad were illustrated and described which have auxiliary or delivery pockets under the

large storage pockets. The delivery pockets are in pairs, each pair holding four and two tons. The coal is dumped into these self-measuring pockets by the tipple man who operates a gate controlling the flow from the storage pocket, from what is known as a measuring pocket platform. The coal can be dumped from the measuring pocket to the tender either from the platform or from the engine cab.

In connection with the discussion of a committee report on "The Most Approved Method of Unloading Locomotive Coal Prior to Being Unloaded on the Tender," at the 1901 meeting of the Master Mechanics' Assn., F. A. Delano, then with the C. B & Q., mentioned a coaling station which delivered coal on each side and which had four track scales, two at each end. The empty tender was first weighed at one end, coal was taken and the tender again weighed at the other end of the coal chute. The scales were twenty feet long and the arrangement had been in operation with satisfactory results for a year, at a point where 125 to 150 engines were handled daily. The matter came to our attention too late to follow it up. If it has been discontinued, due to the scales not being able to stand up under the severe service, it is quite probable that much better results could be obtained at present, due to improvements which have been made in track scales in recent years. If satisfactory scales are available it would seem to offer a comparatively cheap and satisfactory means of securing accurate results.

The coal pits on the tenders can also be calibrated, assisting the coal chute foreman to make a fairly close estimate of the amount of coal issued, but it is necessary to level the coal off before additional coal is dumped in, and this would be more or less objectionable when coaling on the road.

Wastes at Fuel Stations.

Lack of proper supervision and system at fuel stations will result in considerable waste or shortage. Mr. N. M. Rice, general storekeeper of the Santa Fé, recently made a careful study of conditions at the various fuel stations on that system, with a view of bringing about improvements in efficiency and economy.

Investigations.—The first step was to secure accurate information as to the conditions at each station. A personal visit was made to each one and data were obtained and noted on a sheet which was arranged to fit in a loose leaf note book. These sheets were about 5 x 8 in. in size, of fairly heavy paper and certain questions were printed on each side. The questions referring to the coal chutes were as follows:

At.............. Division..............
Date visited.
Class of chute.
Number of pockets.
Capacity of each pocket.
Total capacity, pockets.
Total capacity, bin.
Number of cars chute will hold.
Kind of coal used.
Coal supplied from.
Average No. tons issued, Day...... Night...... Month......
Average No. cars coal received, Day...... Month......
Chute droppings......tons, average per month.
Disposition made of chute droppings.
No. engines coaling, Day...... Night...... Month......
No. of men at chute, Day...... Night...... Extra......
Cost of chute labor.
Cost unloading per ton.
Cars hoisted by.
Make of engine.
How is check made on fuel issued?
Can correct weights be obtained without radical changes being made in chute?
What repairs are needed?
Possibility of loss of coal.
What check on this? (Question above.)
Chute foreman.
Remarks.

The form for the fuel oil stations contained the following questions:

At.............. Division..............
Date visited.
No. storage tanks and capacity.
No. tanks underground and capacity.
No. tanks elevated and capacity.
Total storage capacity of station
Oil supplied from.
Average No. gallons issued, Day...... Night...... Month......
Average No. cars received, Day...... Night...... Month......
Average No. engines taking oil, Day...... Night...... Month......
No. of men at station, Day...... Night......
Cost of labor for unloading.
Method of unloading oil.
How is check made of fuel issued?
Who measures oil issued to locomotives?
Who takes reading for monthly inventory?
Is water drained from tanks?
If so, is record kept of amount drawn off?
Possibility of loss of oil.
What check on this? (Question above.)
Are oil connections leaking or in need of repairs?
Foreman.
Remarks.

Wastes at Coaling Stations.—Mr. Rice's investigations indicated the following possible sources of loss at coaling stations:

Lack of supervision over coal chute foremen. These men, although they may be capable, are not always properly instructed as to the method of recording receipts and disbursements. Reports must be such that they may be checked by the auditing department. Measuring devices should be such that the fuel issued may be measured fairly accurately.

Incompetent chute foremen.

Delay in making necessary repairs at coaling stations.

Overloading engine tenders.

Improper or defective coal gates on tenders.

Wastes at Fuel Oil Stations.—Shortages at the fuel oil stations were found to be due to the following causes (largely due to lack of supervision):

Oil overflowing on the ground because of the unloading vats being too small, or due to carelessness in unloading.

Leaking pipe connections, both above and underground.

Leaks from submerged tanks.

Overflowing engine tenders and service tanks, due to carelessness.

Oil cars in leaking condition.

Engine tenders and engine connections leaking.

Improper opening and closing of valves on tank cars due to incompetent labor, often allowing a considerable amount of oil to escape.

Losses due to the overflowing of elevated supply or delivery tanks when filled by air pressure or steam, and caused by the carelessness of the pumper or the lack of proper regulating devices.

Organization of Fuel Department.

To remedy the above conditions a fuel department has been organized on the Santa Fé and placed under the direction of the general storekeeper. A fuel supervisor has been appointed on each grand division, who appoints and is responsible for the work of all employees engaged exclusively in the receiving, storing, delivering and of accounting for all fuel. He also receives and compiles all reports from the fuel stations and makes such reports as may be necessary to the audit or other departments.

Fuel inspectors (about one to each two divisions) report to the fuel supervisor. These inspectors see that capable men are placed in charge at the fuel stations, both day and night. They are expected to keep in close touch with conditions at the various stations and to take such steps as may be necessary to insure the economical handling of fuel and to prevent waste. They see that coal chute repairs are promptly and properly made, and that the coal chute pockets are properly marked to determine as closely as possible the actual amount of coal issued. They instruct the coal chute men with regard to overloading the tenders and also as to the method of making out the daily reports. They should attempt, in conjunction with the engineer, to reduce the issues of fuel as much as possible, by keeping in personal touch with the firemen. They are expected to ride the different engines, instruct the firemen as to the proper methods of firing and report any mechanical defects. To secure the best results they are furnished with a daily record of the operation of each coaling station and also of the fuel performance of each engine.

Each fuel station is in charge of a foreman. He must not only see that the fuel is properly unloaded and stored, but must measure all the fuel issued and make out the fuel tickets. He is also responsible for the proper loading of the tenders.

Reports in Connection with the Operation of Fuel Stations.

A system of telegraphic reports has been established on the Santa Fé by which the fuel foremen and agents advise the fuel supervisor each morning as to the amount of fuel at each fuel

Hall 1-8 2M 8451

Form 1585 Standard.

Daily Coal Report.

7:00 A. M.______________190___ ______________DIVISION.

(A) STATIONS	(B)	(C)	(D) DA HOPPER CARS	DB TONS	DC OTHER CARS	DF TONS	(F) TONS	(G) TONS	(H) HA CARS	HB TONS	(J) JA HOPPER CARS	JB TONS	JC OTHER CARS	JD TONS	(K) KA CARS	KB TONS
TOTALS																

(A)—Fuel stations.
(B)—Average daily requirements in tons.
(C)—Days' supply on hand in cars, chutes and bins.
(D)—Cars and tons on hand at each station, or moving in trains for this division's supply.
(F)—Tons in storage.
(G)—Tons in chutes or bins.
(H)—Amount of coal in cars, chutes or bins, using billed weights of cars for tonnage.
(J)—Cars Stock A coal held on division for movement to connecting division.
(K)—Received at each station.

FIG. 12.—SUMMARY REPORT FORM FOR TELEGRAPHIC COAL REPORTS—SANTA FE.

station and the number of cars en route, and where located. This gives the fuel supervisor complete control of the fuel from the time it leaves the oil fields or coal mines until it is issued to the locomotive. It enables the company to transfer fuel from one point to another with the least possible delay and prevents the holding of cars at points where they may not be needed immediately, thus assisting the transportation department in keeping more cars in service. The telegraphic reports are followed by detail reports by mail. Fig. 12 shows a summary sheet upon which the telegraphic coal reports are entered each day. The symbols are used to facilitate the handling of the messages.

When delivering coal or oil to an engine the fuel foreman makes out a ticket, Fig. 13, in triplicate; one copy is given to the engineer, another is sent to the fuel supervisor, and the third is retained in the book to protect the fuel foreman. The daily coal performance of each engine is watched closely, as will be described in another section of this article. The fuel consumption per ton mile depends upon the class of service in which the locomotive is engaged and to assist in the preparation of the reports for the different classes of service the coal tickets are of different colors; white for freight service, red for passenger, yellow for switch and blue for mixed freight.

Every twenty-four hours a report is sent to the fuel supervisor showing the issues made during that time and the conditions at each station. Fig. 14 shows the arrangement of this report for fuel oil. The report from the coaling stations is, of course, made on a different form.

The tender tanks are calibrated so that the amount of oil which is taken may be determined accurately. The coaling stations which have pockets are accurately calibrated and it is intended also to calibrate the coal pits on each engine tender.

Education of Firemen.

WHAT IS TO BE EXPECTED:—

When there is only one traveling engineer or fireman to from 400 to 1,500 miles of road.

When green firemen are placed on an engine without

(FORM 1131 STANDARD)

DAILY RECORD OF FUEL OIL ISSUED

*At*______________*Station*______________*190*___

Foreman's Number	Engine Number	ENGINEER	FIREMAN	Train Number	Service	After Taking	Before Taking	Quantity Taken	REMARKS
				TOTALS					

CARS UNLOADED INTO DELIVERY TANK

CAR INT.	NO.	CAPACITY GALS.	DEPTH OF OIL FT.	IN.	DO NOT WRITE IN THESE SPACES ACTUAL GALLONS	DEDUCTIONS PER GAUGE TICKET	SHORT	OVER	REMARKS

OIL INTO DELIVERY TANK FROM STORAGE TANKS

FILLING NO. 1
Gauge Reading After ____*Feet*____*In.*____*Gals.*
" " *Before*____*Feet*____*In.*____*Gals.*
*Amount Taken*____*Gals.*

FILLING NO. 2
Gauge Reading After ____*Feet*____*In.*____*Gals.*
" " *Before*____*Feet*____*In.*____*Gals.*
*Amount Taken*____*Gals.*

FILLING NO. 3
Gauge Reading After ____*Feet*____*In.*____*Gals.*
" " *Before*____*Feet*____*In.*____*Gals.*
*Amount Taken*____*Gals.*

FILLING NO. 4
Gauge Reading After ____*Feet*____*In.*____*Gals.*
" " *Before*____*Feet*____*In.*____*Gals.*
*Amount Taken*____*Gals.*
*GRAND TOTAL*____*Gals.*

This Record is for 24 Hours Ending at 6 p. m. Commencing at that time Tickets Must be Numbered from 1 up Consecutively each day

______________FUEL FOREMAN

FIG. 14.—DAILY REPORT FORM FOR FUEL OIL STATION—SANTA FE.

preliminary instruction as to their work, and are left to shift largely for themselves.

When the traveling engineer or fireman is an ex-engineer who was graduated from firing so long ago that his recollections of it are mellowed and softened by age.

When a traveling engineer or fireman has grown so portly that he cannot fire more than a few minutes before he is tuckered out—even if he has not a "biled" shirt on.

When most roads do not furnish the firemen with any printed instructions as to their duties and the proper method of firing, but often rely upon an inefficient force of traveling instructors who in some instances are entirely unsuited for this work.

When absolutely no record is kept of the coal performance of the different crews—in order that the poor firemen may be located and followed up; or if one is kept it is not issued until from 20 to 90 days after the end of the month and is ancient history before it comes to light.

When coal performance records entirely disregard the effect of poor dispatching and conditions not under the control of the engine crew.

When the amount of fuel issued is oftentimes guessed at by poorly paid and sometimes ignorant hostlers—not always proof against a good cigar.

When the duties of the traveling engineer or fireman often require him to spend the greater part of his time in connection with office work.

When the fireman himself is not ambitious and does not take a proper interest in his work—but what can be expected under some of the conditions mentioned above?

Traveling Engineers or Firemen.—Investigation shows that about two-thirds of the railroads have no special courses of instruction, or printed matter, to guide the enginemen in the economical use of fuel, but depend entirely upon the traveling engineers or firemen to instruct the men. This is all well enough if these men have been properly selected and are the right kind of men; if there are plenty of them, and if they are not loaded down with a lot of other duties which interfere with their riding on the engines and instructing the men. Unfortunately these ideal conditions do not pertain on many roads.

In discussing the qualifications of the road foreman of engines D. R. McBain, of the Michigan Central, spoke as follows before the last meeting of the Traveling Engineers' Association:

"Usually men are selected for these positions (road foremen of engines and traveling engineers) who are successful engineers, who are skilful men, and who are thought by their superiors able to impart such information as their success and skill would denote, to the rank and file of enginemen, where needed. The tremendously skilful man is not necessarily the most successful, as he is likely to give his men the idea once expressed in the hearing of the writer by a conductor who was about to start on his first trip in that capacity, that he drew the pay and what he said 'must go, right or wrong.' A better man for the position of road foreman of engines, or traveling engineer, is the man who will do his best to impart to his men such useful information as he is sure of and discuss with them any other point and not make a decision until he knows.

"Success and skill are not all that is essential in a road foreman, or traveling engineer. Good judgment, a cool head, a temperate tongue and a 'thick skin' are perhaps the best assets he can have, as without them he is not likely to possess the art of 'approaching' in a satisfactory manner, the rank and file of the enginemen with their various dispositions."

In addition to being a good instructor, and a good "mixer," the traveling engineer should preferably be a young engineer who has had a first-class record as a fireman and can get down and fire, when necessary. The remark has been made that if a test for traveling engineers was given, similar to that which President Roosevelt arranged for the army officers in connection with riding, equally good results might be brought about.

How can we expect to secure first-class traveling engineers, with the above qualifications, if the railroads are not willing to pay them more than they could make on the first-class runs?

Literature.—About one-third of the railroads use other measures for instructing the enginemen in the economical use of fuel, in addition to the instruction given by the traveling engineers. This consists in some cases of printed instructions as to the economical use of fuel, which are issued to each engineman; in some instances bulletins are sent out from time to time; in still other cases fuel meetings are held.

Only a few roads issue instruction books. On two roads, the Chicago, Burlington & Quincy, and the Great Northern, these books are quite elaborate. They include a section on economical firing, which treats of the theory of combustion and the proper methods of firing under varying conditions; a chapter on economical boiler feeding and one on the economical use of steam. Other roads furnish booklets, which may be purchased upon the open market, such as "Information," by George M. Carpenter, fuel expert of the Nashville, Chattanooga & St. Louis Ry., or "Fuel Economy," by George H. Baker.

Form 1122-C Standard.

Santa Fe. №. 39202 M

FUEL OIL TICKET.

Foreman's No.......... ....Station..........190....

FOR MIXED AND WORK SERVICE ONLY.

Initials.......... Engine.......... Train..........

From.......... To..........

Reading after taking ....Gallons.

Reading before taking..........Gallons.

Quantity taken..........Gallons.

..........Engineer.

..........Fireman.

..........Fuel Foreman.

FIG. 13.—FUEL OIL TICKET.

Several roads issue bulletins on fuel economy from time to time. One of the most successful bulletins of this kind is known as "Circular Letter No. 550," issued a number of years ago by R. Quayle, superintendent of motive power of the Chicago & North Western Railway. At that time the question of proper firing was attracting a great deal of attention and different roads were issuing instructions of various kinds as to the proper use of fuel. Mr. Quayle prepared a letter in which he called attention to the necessity for the cooperation between the engineer and fireman and followed this with what is known as a chapter of "don'ts." The result was a marked increase in efficiency and economy. These "don'ts" are as follows:

DON'T think because you are only one engineer or fireman, that what you do does not amount to much. It is the little drops of water that make the mighty ocean, and the little grains of sand that make up this earth of ours; so each individual, in the aggregate, can do a great deal. If each engine crew saves one-quarter of a ton or five hundred pounds of coal, this on a thousand locomotives would result in a daily saving of two hundred and fifty tons, or in round figures $157,000 a year.

DON'T neglect being at roundhouse in ample time to examine the firing tools on the engine before leaving the roundhouse. See that your ashpan, grates and flue-sheets are in good condition to make the run.

DON'T fill the boiler full of water as soon as you get out of the house. Leave a space so the injector can be worked to prevent popping, while air pump exhaust is fanning the fire, pumping air to make the terminal air brake test. If you do this your fire will be in better condition to pull out with. The noises of open pop prevent trainmen from locating leaks.

DON'T forget to start the lubricator a few minutes before leaving a terminal. Set it to feed regularly. The proper lubrication of valves and cylinders saves coal.

DON'T forget when starting trains, to do so carefully, thus preventing damage to drawbars and draft rigging. By so doing you will save serious delays to your own as well as other trains. All delays mean extra fuel consumption to make up time lost.

DON'T neglect using the blow-off cock, as it keeps the boiler clean and

water in good condition, and insures better circuation in boiler. Result: Better steaming engine and a saving in coal.

DON'T allow the engine to slip. This is an unnecessary waste of coal, wears out tires and rails, causes great damage to pins, axles and running gear, and generally results in spoiling a fire.

DON'T pull out of a station with a train (after engine has stood for a while, and fire was allowed to get low) without first giving the fireman a chance to build up the fire. The time lost waiting to do this will save coal, and can better be made up before reaching the next station. Remember this when you get a time order.

DON'T leave the reverse lever down in corner longer than necessary when pulling out of stations. No rule can be made to govern how the throttle and reverse lever should be used. This must be acquired by practice and observing the performance of the engine. Bring the lever up gradually, as speed is acquired. The lever hooked well towards center of quadrant, with throttle well open, usually gives better results than using the throttle to govern the speed. Up to five years ago we considered it good practice with our smaller power to run with wide open throttle, and as short a point of cut-off as possible consistent with weight of train, but in our heavier and larger engines we find that it is better at many times to throttle the engine. Particular attention is called to all wide fire-box type locomotives. The engineer can permit the reverse lever in these engines to remain low in the quadrant when starting from a station, for a greater length of time than with the other types of locomotives, without pulling the fire or losing steam. When you are running on short time, it would be good judgment for the engineer to take advantage of this when pulling out from a station. In this engineers will use their best judgment.

DON'T put four or five or more shovelfuls of coal into the fire at once. One or two shovelfuls will give better results, and these two should not be thrown in the same spot. It is good practice to fire on one side of the box at one time, and the next time on the other side of the box, in order that the bright fire on one side may take up the gases from the fresh coal on the other side. This will reduce the smoke and give more steam.

Always fire as light as possible consistent with your work. Very heavy firing will make your flues and staybolts leak, and in time will crack your fire-box sheets. The reason for this is that when you have a very heavy fire, the air will not pass up through it readily, and the gases pass off, because there is not sufficient oxygen to unite with them to produce combustion, and as the gases must get air from somewhere, the air is then pulled through the fire-door, causing the chilling of flues and sheets as referred to above.

DON'T allow steam to escape at pops unnecessarily. Frequent blowing off at pops shows improper judgment, and implies that the engine crew is not practicing economy. Tests have demonstrated that ¼ lb. per second or 15 lbs. per minute is wasted. This amounts to about one ordinary scoopful, and in most cases may as well have been thrown on the ground as into the fire-box. There are only 133 scoopfuls in a ton of coal, so you can see that you would only have to have your pops open one hundred and thirty-three minutes in a whole day in order to throw a ton of coal away.

DON'T open the fire-box door to prevent steam blowing off at pops when engine is working: dropping dampers is a better practice. The supply of air is cut off, and combustion is partially suspended. When engine stops blowing off, open dampers again, before putting in coal. This method keeps fire in better condition and saves coal. You have no doubt noticed that on Class R Locomotives, when working hard on a hill, you have to shut your dampers in order to keep your fire from turning over. This is because the exhaust pulls too much air up through the grates, and causes your coal to be too active, and to prevent this activity of coal as well as increased combustion which follows, we consider it a good thing to drop your dampers, as per above.

DON'T insist on having the maximum steam pressure with pops opening occasionally when handling light trains, when less pressure will handle the train on time, thus avoiding the opening of pops.

DON'T forget, when engine is shut off for stations, to drop your dampers, opening the fire-box door slightly if necessary, and using the blower to carry off the black smoke.

DON'T blame the engine or coal, if engine is not steaming properly, before you have ascertained whether or not both of you are doing your duty. Talk it over; see if injector is not supplying more water than is being used, or that fireman is not firing too light or too heavy. Heavy firing is responsible for more poor steaming engines than the lighter method. You all know some engine crews have better success than others with the same engines and conditions. Think a little: there must be some cause for this.

DON'T wait until you get the signal to pull out before building up the fire. This should be done gradually until the proper thickness has been reached. A good fire to start with is essential to maintain the proper steam pressure, while engine is working hard getting train under way. Afterwards distribute the coal evenly on sides, ends and corners. Do this systematically, keeping in mind where you have placed the last shovelful, thus avoiding getting holes in fire,and prevent piling up coal all in one place. Endeavor to keep the steam pressure uniform, with as little black smoke as possible. Experience has taught that engines with draft appliances properly adjusted require very little coal in center of fire-box.

DON'T permit the water to get so high in boiler that it is carried over into the valves and cylinders. This usually occurs when pulling out of stations, and the water carries off the oil, which not only results in cut valves and cylinders, but the extra friction damages the entire valve motion, to the detriment of the power of engine and the coal record.

DON'T gauge the amount of water an engine will safely carry by water coming out of stack. Keep it low enough to insure dry steam being used, because moist steam has the same effect as water. Usually one-half glass or two gauges give best results. Be careful, however, that when ascending a grade, and you are about to pitch over the other side, that you have sufficient water to keep your crown-sheet thoroughly covered. If your custom has been to carry high water, try less and note results in better handling of tonnage, also saving in coal and oil.

DON'T neglect to take advantage of your excess steam before your engine is about to pop off, by making a heater of your injector, blowing steam back into the tank to warm the cold water, but avoid getting it so hot that the injector will not lift the water. By doing this you will keep your engine from blowing off at pops, when standing at stations after the boiler is filled up. You have all tried warming the water in the tank to help a poor steaming engine, with good results. What is good for a poor steaming engine will surely help a good steaming engine do better. Try it and you will find that it will not only save work for the fireman, but will make a better coal record for the engine crew, besides keeping the tank from sweating, which you are aware spoils paint.

DON'T think the fireman alone to blame for your coal record. The best and most economical fireman cannot make a showing with an engineer who supplies more water to boiler than is being used, and who shuts injector off only when boiler is pumped full. The proper handling of the injector is one of the most important matters in saving coal. Feed water to boiler according to demands. If on through train, keep water level as possible. If on way freight or switch trains, lose a little water between stations. Fill up again while drifting into, standing or switching at station. The advantages of supplying less water than is being used between stations are: It requires less coal to keep up steam pressure when running; also leaves a space so injector can be worked to avoid pops opening, and heavier fire can also be maintained to do switching, without the possibility of the fire being pulled.

DON'T pull out, after making a stop, with injectors working. The cool water introduced during period throttle was shut off is put in circulation throughout the boiler, and pointer on gauge drops back from five to twenty-five pounds. The fireman must then fire heavier to regain the lost steam, and naturally will use more coal. This condition exists also when engine has gone down grade with throttle shut or slightly open. Shut the injector off before opening the throttle. If this is not your practice, try it and note the difference.

DON'T wait for the pops to open, and use this as a signal to put on the injector. Keep an eye on the air gauge, steam gauge and water glass. You all know this can be done without detracting your attention from the track ahead. A look for an instant every mile or two will keep you informed, and is a good habit. Doing this will also keep you posted on air pressure, and may avoid difficulties should the air pump stop. The fireman should also keep an eye on the water glass, as the engineer is sometimes compelled to keep the injector at work to prevent the engine blowing off. When glass is full, the fireman should fire lighter, to give the engineer a chance to shut off the injector, and not have engine blow off. However, this condition should only exist when injector cannot be worked fine enough to just supply amount used. This sometimes occurs when card time is slow, or on down grade, or when running with light train.

DON'T put too much coal under the arch of engines with sloping fire-boxes, because these engines naturally pull the coal ahead, which results in forward section of grates becoming stuck and clinkered over, and fire is pulled in back end of fire box. Experience and observation will teach you to put most of the coal in back end of fire-box.

DON'T think engine having two fire-box doors requires twice the quantity of coal it would if it had but one. The extra door is for the purpose of distributing the coal more evenly over the grate surface, with less effort on the part of the fireman.

DON'T shovel large chunks of coal into fire-box, because you find them on the tank. The coal house men have instructions to break it the size of an apple. If not properly broken, report it to road foreman of engines or to master mechanic, instead of fellow engineers or firemen, but don't think it a hardship to break some occasionally. Better break it than to throw in large chunks. They are foundations for clinkers.

DON'T expect the fireman to fire the engine with one or two scoops to each fire, and also ring the bell for highway crossings and stations. Some engineers expect this. If engine is equipped with an air bell-ringer, get into the habit of starting the bell-ringer when blowing the whistle. By so doing, the habit will become as fixed as whistling for crossings and stations. Besides, it is just as important. Remember the engineer is responsible.

DON'T put in a heavy fire about the time the engine is shut off for a station or down-grade. The heavy cloud of black smoke is evidence the engine crew is not working in harmony or practicing economy. If on train that stops at all stations, the fireman should guard against it and learn when to stop firing. He will be governed by grade, service and weather conditions. If train does not make all station stops, the engineer should keep the fireman informed of intended stops.

DON'T forget that different qualities of coal and different makes of grate used, govern the shaking of grates. Coal that fills up and clinkers, requires more attention than the better grade. The object is to keep the grates free so the proper amount of air can be admitted.

DON'T neglect cleaning your fire on trains that are long hours on the road. Make use of the first opportunity. You will get better results with less labor and coal, and avoid leaky flues. Better clean out a small amount two or three times than not clean it at all.

DON'T take coal or water oftener than necessary, as it requires an extra amount of coal to again get a heavy train in motion, especially on a grade.

Good judgment is required, in order not to run short before getting to next coal chute or water tank. Where possible take water only from tank containing good water, and as little as you can from tanks containing poor water.

DON'T forget that leaks in the air pressure are being kept up by an equal amount of steam pressure. As it takes coal to make steam, air leakage means a waste of coal. Keep apparatus on your engine tight, and insist on trainmen doing their part.

DON'T try to put more coal on tank than will lay on it securely. All coal dropped off by overloading is wasted. Also keep coal from falling out of gangway when running. This may be only a little each day, but it all counts against your coal records, besides it looks badly when strewn along the tracks. You can not save coal by the ton; it must be in pounds, which in time make tons.

DON'T forget to make an intelligent report on your work slip on arrival at roundhouse. Consult your fireman in regard to any defect that has come to his notice, especially with grates, dampers or firing tools.

DON'T neglect reporting the pop valves ground in when leaking or when they blow back eight or ten pounds before seating. Also report leaky piston rod and valve stem packings, or if cylinder packing or valves are blowing. All these leaks draw on the coal pile unnecessarily; it takes coal to generate the wasted steam. This also applies to leaky steam heat appliances, cylinder cocks, etc.

DON'T neglect looking at coal report each month to see how you stand in relation to others in same service with whom you are comparable. The other crews get the same pay you do, and it should be your aim to be as economical with both fuel and supplies as they are, other things being equal. Keep posted and be with the average. It will be to your credit and interest some time; therefore aim to be at the top.

DON'T think when coal report shows you using only two pounds more per 100 ton miles than other crews in same service, it is close enough. This means two pounds more used for every mile you hauled 100 tons—or another way, two pounds for every 100 tons hauled one mile. Figure this up and you will find in hauling 1,000 tons 100 miles, a difference of 2,000 pounds or one ton. This method of showing up the individual record is more equitable to all than on basis of miles run per ton of coal.

DON'T think, after reading over this chapter of "DON'TS" you should save coal to the detriment of the service. The actual amount required to make up time, keep on time, or handle tonnage, is not what we are trying to save; it is the waste. You will notice the proper method of handling the engine to the extent of the economical use of fuel only has been considered.

Fuel Meetings.—On several roads fuel meetings are held from time to time. On the Chicago, Milwaukee & St. Paul these coal meetings are held at the various division points three or four times a year. In addition to the engineers, firemen and mechanical officials, the local operating officials are also present. The men are encouraged to express their views and criticize methods and these meetings have been instrumental in bringing about splendid results, not only as concerns the work of the engine crew but also in connection with the operation of the trains, etc. On another road in the middle west the assistant superintendents of motive power recently went over the divisions where they were best acquainted and hired halls and talked to the enginemen on the economical use of coal.

Coal Premiums for Enginemen.

The practice of paying premiums to enginemen for the economical use of fuel is being used extensively abroad. It has been tried to some extent in this country—has in fact been used for a number of years on several large systems. Two important roads have recently discontinued the practice in this country and as far as we have been able to ascertain it is not now in extensive use on any road.

Some of the more important reasons urged against its use are as follows: The systems ordinarily used for determining and checking the amount of coal placed on the tender are far from perfect; the grade of coal used on many roads varies considerably, sometimes even on the same division; the engine crews are not credited with excess consumption of fuel due to poor dispatching and adverse conditions not under their control; the condition of power is far from uniform. Possibly the most important reason is that fuel is comparatively cheap and as yet there is not the same stern necessity for fuel economy as there is abroad. Undoubtedly the time is not far distant when the railroads may be forced to practice far greater economy than is now used and conditions will gradually come about which will make it possible to secure the same careful, systematic service from enginemen as is found in England and on the continent.

Among several questions on the use of fuel on locomotives, which were recently submitted to a number of superintendents of motive power was this: Do you pay your enginemen premiums for the economical use of fuel? The answer was in all cases in the negative. Extracts from three of the letters, which touch upon this question, are as follows:

"We maintained a coal premium system for many years. It was discontinued at a comparatively recent date, with the idea that by the addition of instructors, and an increase of inspectors, the economical use of fuel would be promoted better than with what had gotten to be a very complex system of coal premiums."

"The premiums given to enginemen for saving in fuel have lately been abolished, as it has not proven economical. This system was based on the ton mile."

"For a number of years we kept an individual record of the coal consumption by each engineer, and gave them a credit mark each month based upon the number of pounds of coal per loaded car mile; but, after a thorough trial for a number of years, we reached the conclusion that there were so many variables entering into the computations that they were really not accurate, and, in some cases, misleading. I think the engineers themselves became impressed with this idea, and lost interest in endeavoring to secure high rank on fuel performance. The men who made the best records in many cases are the same men who have since maintained good fuel records, and would do so under any conditions, they being the men whose interest and pride is in doing their life work well; the other class are hard to reach or to stimulate; we, therefore, after carefully considering the matter, felt that the expense of keeping individual records was not justified, and that form of record has been dropped; for the same reasons, we do not pay fuel premiums to engineers or firemen."

Some railroad officers believe that a premium system established under proper conditions offers one of the most inviting means of effecting economies, not only in the use of fuel but in other directions. The indications are that the matter will be tried out on at least one road and under conditions which will be radically different from anything which has been done heretofore in this country.

The premium system on one of the French roads was described on page 91 of the March, 1905, issue of this journal in connection with one of G. M. Basford's letters on "Impressions of Foreign Railroad Practice." This road pays premiums not only for fuel economy but for making up time when the enginemen are not responsible for the delay, for economy in lubrication, and for runs independent of premiums for economy. They are fined for excessive fuel consumption and irregular runs. These fines are rigidly enforced unless the engineer can prove that it was due to some cause over which he had no control.

Fuel Premiums for Traveling Engineers.

One road pays its traveling engineers premiums based on the average fuel consumption for each division. Allowances are made for each class of service, as follows:

Heavy passenger trains, one ton per 10,000 ton miles.
All stock or time freight trains, .8 ton per 10,000 ton miles.
All other freight trains, .9 ton per 10,000 ton miles.
Switch, work trains or helper engines, .25 ton per 10,000 ton miles.
Idle under steam, .025 tons per hour.

The superintendent of each division keeps an accurate record for each engineer and fireman, showing the coal consumed for each trip, the coal allowed and the excess.

The traveling engineers have a fixed salary of $125.00 per month. In addition they receive $1.00 for each point the percentage is reduced below the allowance for the first 10 points and $5.00 per point thereafter. Changes are made in the schedule to allow for winter and summer weather. Very satisfactory results are claimed for this method.

Fuel Performance Records.

Daily versus Monthly Reports.—The monthly engine performance reports, as compiled on most roads, are not issued until from 15 to 60 days after the end of the month and are of little value in checking up the fuel performance of the different crews. While they show the relative performance of the different crews in a general way, they do not distinguish clearly enough—in most cases—between the different kinds of service in the same general class, nor do they take into consideration conditions which may materially affect the fuel consumption, but which are not under the control of the enginemen. Because of this, these reports seem to have gradually lost their value as a means of spurring the men on to better efforts.

Realizing this, at least four roads have established what is known as "daily engine performance reports" which show the

tonnage, fuel consumption, weather conditions and train movement of each run. These reports are issued the day following, or at the latest the second day after the trip. In general, excessive fuel consumption is due to adverse weather conditions, poor train movement, poor fuel, a defective locomotive or poor work on part of the engine crew. If the weather conditions and train movement are favorable the responsibility for poor performance lies between the fuel, condition of locomotive and the crew. The matter is at once taken up with the roundhouse foreman and the engine crew, and the trouble is located. These reports have resulted not only in the more economical use of fuel, but have called forcible attention to the poor condition of locomotives and fuel. In some instances they have been the means of bringing about better train movements.

The four railroads using the daily report system are the Chicago, Milwaukee & St. Paul Railway, the La Crosse division of the Chicago, Burlington & Quincy, the Great Northern Railway and the Atchison, Topeka & Santa Fe Railway. The methods of collecting and compiling the data for the "daily reports" on these roads, and in fact the reports themselves, differ considerably, although they are intended to accomplish the same general result. This may be seen from the following descriptions:

Daily Engine Performance Reports.

Chicago, Burlington & Quincy.—In 1905 Mr. N. Frey, master mechanic of the La Crosse division of the Chicago, Burlington & Quincy Railroad, put into effect a system of daily engine coal and delay reports, which not only effected a considerable saving in fuel but has otherwise improved the service.

The following results gained during 1905 and 1906, as compared with 1904, are of interest:

COAL PERFORMANCE.

Through Freight Service.

	1904.	1905.	1906.
Total ton miles	1,133,402,447	1,265,182,755	1,401,072,722
Tons coal used	85,823	86,712	89,192
Lbs. coal per 100 ton miles	15.1	13.7	12.7

Improvement in Pounds of Coal Used per 100 Ton Miles.

1905 over 1904	1.4 lbs.
1906 " 1904	2.4 "
1906 " 1905	1.0 "

To handle 1905 tonnage on basis of 1904 would require 8,856 more tons of coal valued at $15,055.00. To handle 1906 tonnage on basis of 1904 would require 16,862 more tons at a cost of $28,665.00. To handle 1906 on basis of 1905 would require 7,005 more tons at a cost of $11,910.00.

This system was not applied to passenger service until 1906. The following is a comparison of the results gained during that year and 1905:

COAL PERFORMANCE.

Passenger Service.

	1905.	1906.
Total car miles	3,048,016	4,152,334
Total tons coal used	25,047	28,855
Lbs. of coal used per car mile	16.4	13.9

Saving 1906 on Basis of 1905.

In lbs. per car mile	2.5
In tons of coal	5,190
Value of coal saved	$8,853.00

One of the daily coal performance sheets is shown in Fig. 15. The division superintendent furnishes the items "engine," "train," "miles," "tons" and "engineer" from the dispatcher's train sheet. The coal clerk in the master mechanic's office adds the tons of coal used and the fireman's name, and calculates the ton miles and the pounds of coal used per 100 ton miles.

The engineers are required to fill out a delay report for each trip, Fig. 16. The cause of the delay is entered in the column headed "remarks." When the coal clerk has completed the coal performance sheet he attaches the delay reports to it and hands it to the master mechanic. If the coal consumption per 100 ton miles is excessive for a certain run the master mechanic or the road foreman of engines can refer to the delay report and see the exact conditions under which the run was made. If the delays on the run are not excessive and the weather conditions are favorable something must be wrong with the grade of fuel, the firing, or the engine, and the matter is at once taken up with the engine crew and the roundhouse foreman.

At some points on the division the coal is actually weighed when it is delivered to the engine; at others it is measured in buckets, while in some cases the hostler estimates it. The tenders start from the terminal with a full load. Wherever coal is taken the hostler fills in a slip in the engineer's coal book and tears it out and forwards it to the master mechanic's office by mail. Before the small slip is torn off (there are three of them attached to each large slip) the proper notation is made on the large slip shown in the illustration (Fig. 17) and on the stub, which is similar to it. At the end of the run coal is taken; the amount burned on the trip is therefore equal to that taken on the run and at the end of the trip. The hostler at the terminal forwards the large coal slip to the master mechanic's office. The daily coal performance reports are being used in connection with the way freight service, as well as with the through freight and passenger service. The results with the way freight are, however, not as accurate, as the tonnage used in the calculations is that of the train when it reaches the terminal. It has been found that this usually agrees quite closely with the actual average tonnage during the run. If necessary, the actual tonnage could be secured but the conditions on this division are such that it is not thought necessary.

The cost of keeping these records is about $25.00 per month. In addition to checking up the poor enginemen it has been found of great value in locating mechanical defects. The engines in the through freight service are pooled and if a certain engine shows up poorly with two or three different engine crews the roundhouse foreman is asked to give it a thorough inspection, and invariably something is found to be wrong, such as leaky steam chest bushings, steam pipes, etc. When the report was first started seventeen loose piston valve bushings were located and renewed. Under ordinary conditions these would probably not have been discovered for a considerable time.

The delay reports are quite necessary in connection with the coal reports, as they place the responsibility between the operating and mechanical department and the engineman is not called

ENGINEER'S DAILY COAL PERFORMANCE.

Date Aug. 3rd 1907

Engine	Train	Miles	Tons	Ton Miles	Tons Coal	Pounds Per 100 T. M.	Engineer	Fireman
2032	X	157	2,260	354,820	22	12.4	Allison	Nicolay
1906	80	"	1,850	290,450	16	11.0	King	Layland
2103	X	"	2,550	400,350	20	9.9	McEldeny	Haiden
2042	X	"	1,660	260,620	20	15.3	Galloway	Irwin
2028	81	"	2,020	326,560	16	9.8	Boyer	Smith
[illegible]	77	"	2,710	425,470	23	10.8	[illegible]	[illegible]

FIG. 15.—DAILY COAL PERFORMANCE REPORT, LA CROSSE DIVISION OF CHICAGO, BURLINGTON & QUINCY RAILROAD.

Train 81 From Sav. Yd to G. Xing Date 8-3-07.

Stations	Meeting Passing	Set Out Pick up	Coal or Water	Orders Block	Hot Box Eng. Cars	Misc. Delays	Remarks
G Xing							
LaCrosse							
South Jct.		10					Set Out
Stoddard						20	Surfacing Gang
Rusk	10						Ex. 273
Genoa	10						Track Gang
Victory		5	10				Pick up - Water
De Soto							
Ferryville	15						Meet 52
Lynxville							
Charme							
Pra. du Chn.		10	10				Set Out - Water
Crawford							
Wyalusing							
Bagley							
Glen Haven						5	Unload
Dewey							
Cassville	22		6				Meet Ex. 2032 - Coal
McCartney							
Potosi						5	Unload
Blake							
Rutledge							
E. Dubuque		10	10				Set Out - Water
E. Cabin							
Portage				5			Block
Galena Jct.							
Hanover							
Marcus							
Savanna						10	Unload
Total	57	35	36	5		40	

Departed 5[16] a.m. Arrived 4[10] P.M. Hours 11

Average speed, delays excluded 19.4 No. cars 61

Engine 2028 Engineer Boyer

Weather Cond. Clear Fireman Smith

FIG. 16.—ENGINEER'S DELAY REPORT, C. B. & Q. R. R.

to account when the fault is in the dispatching. Monthly performance sheets are also prepared and posted in the roundhouses. The accompanying table shows part of one of these monthly reports. The crews are divided into what is known as first and second class; those in the first class have a coal record better than the average and those in the second class below it. The record reproduced is for through freight service. Separate reports are issued for way freight service and passenger service.

PERFORMANCE OF ENGINEERS IN FREIGHT SERVICE ON LA CROSSE DIVISION.

Month of December, 1907.

Engineer.	Fireman.	Total Ton Miles.	Tons Coal.	Pounds per 100 Ton Miles.	Cost for Hauling 1,000 Tons 1,000 Miles.
First Class.					
Lakowsky, F. E.	Fisher	3,290,605	162	10.0	85.00
Snyder, C. J.	Smith	5,908,873	299	10.0	85.00
Larson, C. L.	Bell	2,482,766	146	11.8	100.30
Johnson, W. S.	Pruetz	2,957,526	183	12.4	105.40
Boyer, John	Dixon	5,564,709	353	12.7	107.95
Total and average:—					
This Mo.		122,554,778	8472	13.8	117.30
Same Mo. last year		131,192,432	9305	14.2	120.70
Last Mo.		154,952,831	10553	13.6	115.60

Chicago, Milwaukee & St. Paul Railway.—The Chicago, Milwaukee & St. Paul Railway has had in effect for a considerable time what is known as the "Train Dispatcher's Daily Report of Train Tonnage and Coal Consumption." The form for this report is shown in Fig. 18. The conductor wires in the gross tonnage of the train from certain points known as "tonnage points," places where a change is usually made in the tonnage.

The coal pits of the tenders are supposed to be filled when the train leaves the terminal. The foremen at the coaling stations wire in, once a day or more, the amount of coal given to each engine. The dispatcher determines the total amount of coal used on the trip by adding the amounts for each engine, including that when the tender is filled at the end of the trip. With this information in hand it is the matter of only a few minutes to calculate the other information on the form. To facilitate the making of these calculations a set of tables, in book form, has been arranged by Mr. W. M. Harvey, auditor of material accounts. These are arranged so that it is possible to quickly find the ton miles, knowing the tonnage and mileage. Having found this and having the pounds of coal used on the trip, other tables are included to determine the pounds of coal consumed to haul 100 tons one mile.

These daily reports are completed the day following, or at the most the second day after the run. One copy of the report is sent to the auditor of material accounts and the other is kept by the dispatcher. If the fuel consumption is excessive for a certain trip and the train has not been badly delayed and the weather conditions have been favorable, the matter is called to the attention of the mechanical department, and the condition of the engine is looked into and the enginemen are called upon for an explanation.

Based upon these train dispatcher's reports a statement is prepared each month by the auditor of material accounts, showing the train miles, ton miles and average tons per train for the east and west bound trains on the different divisions; also the train miles, ton miles, average tons per train, pounds of coal consumed, average pounds of coal per 100 ton miles and average miles per hour for all of the trains on each division. This is for main line service only and makes it possible to compare the average performance on the different divisions. Under the "average tons per train" and "average pounds of coal per 100 ton miles" are three columns, so as to show the comparative figures for the same period during the previous year and the gain or loss over that year.

Atchison, Topeka & Santa Fe Ry.—In connection with the organization of the fuel department on the Santa Fe (see page 134), it has been found advisable to institute a system of daily engine performance reports to assist in locating the poor firemen and following them up, to locate mechanical defects or defects in design which may effect the coal economy, and to check the improper dispatching of trains.

The daily coal performance sheet may best be understood by reference to Fig. 19. As may be seen the greater part of this form is prepared from the train dispatcher's report. The information in the column marked "not to be filled in by train dispatcher" is filled in by the fuel supervisor. The coal or fuel oil consumed is taken from the daily reports sent in by mail from

M-11-07-750 Form 4181. 3

Burlington Route Chicago, Burlington & Quincy R. R. Co.

Engine No. ....

.... Engineer

.... Fireman

Date .... 190.... Train No. ....

From .... To ....

Date .... 190.... Train No. ....

From .... To ....

Coal in Tank at start, ... Lbs.

Coal Taken at .... Tons

Coal Taken at .... Tons

Coal in Tank at end of trip, ... Lbs.

Total Coal consumed, ... Lbs.

Coal Taken at .... (For next trip) .... Tons

3

Burlington Route C., B. & Q. R. R. Co.

Engine No. ....

.... Station

.... 190....

Coal .... Tons

Wood .... 16th Cords

Charge ....

....

Engineer.

FIG. 17.—COAL TICKET, C. B. & Q. R. R.

Form 561

CHICAGO, MILWAUKEE & ST PAUL RAILWAY.

TRAIN DISPATCHER'S DAILY REPORT OF TRAIN TONNAGE AND COAL CONSUMPTION

.... Division. .... Date........ 19

TRAIN NO	TRAIN MILES	CONDUCTOR	ENGINE NO.	ENGINEER	FIREMAN	TONNAGE LEAVING	TON-MILES	AVERAGE TONNAGE PER TRAIN	COAL CONSUMED	POUNDS OF COAL PER 100 TON MILES	TIME IN SERVICE HRS.	TIME IN SERVICE MIN.	REMARKS
EAST BOUND.													
TOTAL AND AVERAGE.													
WEST BOUND.													
TOTAL AND AVERAGE.													
GRAND TOTAL AND AVERAGE.													

Percentage of rating hauled........

.... DISPATCHER.

FIG. 18.—TRAIN DISPATCHER'S DAILY REPORT OF TRAIN TONNAGE AND COAL CONSUMPTION, C. M. & ST. P. RY.

Form 814 Standard

Santa Fe.

.... DIVISION. .... (Insert name of Railway.)

DAILY TRAIN TALLY SHEET, AND TRAIN DISPATCHER'S REPORT OF TRAIN TONNAGE AND FUEL CONSUMPTION PER 100 TONS MILES IN .... SERVICE. DATE .... 19__

Train No.	Kind Train	CONDUCTOR	ENGINEER (Initials and Name in full)	FIREMAN (Leave blank)	Engine No.	From	To	Actual Train Miles	Time Called	Time Left	Time Arrived	Total Time in Service Hrs.	Total Time in Service Min.	No. of Stops	TONNAGE LEAVING	Ton Miles (Not to be filled in by Train Dispatcher)	Coal or Oil Consumed (Not to be filled in by Train Dispatcher)	Average Tons per Train (Not to be filled in by Train Dispatcher)	Average Pounds of Coal or Oil per 100 Ton Miles (Not to be filled in by Train Dispatcher)	REMARKS If Light Engine show reason for running, etc.

NOTE. Be very careful to enter but one engine on a line.
Be very careful to show run of each engine outside of yard limits, including double-headers, helping and light engines, and engines doubling hills (both up and down).
In "Kind of Train" column state if train was freight, passenger, mixed, special, work, construction, light engine, engine helping passenger train or engine helping freight train.
When work train runs some distance and then works between two points, be careful to show movement running and movement working, separately, giving time starting and stopping in each item.

This sheet to be made up in duplicate in Train Dispatcher's office daily, and forwarded without delay as follows:

For The A. T. & S. F. Ry., to: Ticket Auditor, Topeka. Car Accountant, Topeka. Three copies to Fuel Supervisor, Topeka.

For G. C. & S. F. Ry., to: General Supt., Galveston. Auditor, Galveston. Three copies to Fuel Supervisor, Cleburne

For A. T. & S. F. Ry., Coast Lines, to: Car Accountant, Los Angeles. Auditor, Los Angeles. Three copies to Fuel Supervisor, San Bernardino.

For E. Ry. of N. M. System and S. K. Ry. Co. of Tex., to Auditor, Amarillo.

Weather conditions........

Conductors are instructed to date their Train reports the day on which the train leaves, and the object of this sheet being to correct Conductor's reports, it is important that all Trains leaving Division stations before 12 o'clock, midnight, should be included.

In giving time when trains leave and arrive, be careful to say whether it is "A. M." or "P. M.," as in tracing cars of time freight it is necessary to know the exact time of arrival and departure of trains.

Construction and work trains are to be included in this sheet, showing between what stations they are at work.

All light engines must be shown, and in column of "Remarks" reason for movement entered, as "To even power," "Pusher returning to proper position," etc.

Reason for any unusual delays to trains must also be shown.

Make separate report for passenger and freight service.

....

Chief Train Dispatcher.

FIG. 19.—DAILY REPORT OF TRAIN TONNAGE AND FUEL CONSUMPTION, SANTA FE.

the fuel stations; the other items are calculated in the office of the fuel supervisor. These reports are ready within two or three days after each trip. The information on this sheet enables the fuel supervisor to determine at once whether excessive fuel consumption is due to poor dispatching, weather conditions, or to poor firing and a defective engine. If due to the latter causes, the matter is at once taken up with the engine crew, while it is still fresh in their minds. The results have been very satisfactory.

Two simple monthly performance reports are also used to advantage. One of them, Fig. 20, is for the operating officers and is a check on the train movement and fuel consumption. The second, Fig. 21, shows the fuel performance for the different engineers or engines and is posted in the engine houses each month. The last two columns show the total money gain, or loss, based upon the average cost per ton mile and serves to bring the importance of fuel economy forcibly before the men.

Great Northern Railway.—A daily bulletin of the performance of enginemen (Fig. 22) is posted at the division terminal roundhouses and copies are furnished to the road foreman of engines, master mechanics and superintendent of motive power. This statement covers road enginemen only; enginemen in service at

Hall 11 07 3M 7936

Form 1132 Standard.

Santa Fe.

.................................DISTRICT. ....DIVISION.

Engineer .... 190....

Date	TRAIN No.	FIREMAN	ENGINE No.	STATION		TRAIN MILES		TOTAL TIME		No of Stops	TON MILES		COAL OR OIL CONSUMED	REMARKS
				From	To	East	West	Hrs.	Min.		East	West		

FIG. 20.—MONTHLY FUEL PERFORMANCE REPORT FOR USE OF OPERATING OFFICIALS, SANTA FE.

other than division terminals are not considered owing to the difficulty of getting information promptly. These statements are posted in the roundhouse early each day and excessive consumption of coal and oil, and delays due to engine failures are promptly investigated by the road foreman of engines. If the amount of coal used is excessive in comparison to the time on the road, size of train, etc., the roundhouse foreman is instructed to make a careful examination of the engine and if it is found to be in good condition the matter is taken up with the engine crew. In this way cases of improper handling of the engine and poor firing are often located. Excessive time on the road and bad delays are referred to the superintendent and trainmaster.

These bulletins are said to be responsible for the prompt correction of such defects as leaky steam pipes, improper draft, worn packing rings, etc., as the engineers are careful to report all necessary work, and if the coal consumption is high special efforts are made to locate the cause. As may be seen by referring to the form, the train dispatcher, roundhouse foreman and engineer are each expected to fill in independently certain of the columns, in some instances offering a check upon each other and insuring accurate information. The figures for column 12 are taken from the coal ticket stub, which is filled in by the engineer and is turned in by the hostler after the tender is filled at the end of the trip. Columns 12, 13, 14 and 16 are furnished by the oil house man at the terminal and the engineer makes a report of any oil or waste taken at other points on the trip. The coal ticket is practically the same as that used on the Chicago, Burlington & Quincy, as illustrated on Fig. 17. The hostlers judge as to the amount of coal taken.

No monthly statement is issued as to the performance of the enginemen, but a statement is made up each month showing the performances of the different classes of iocomotives on each division. This shows the mileage made by each class of engines, including light, freight, passenger, mixed, helper (freight and passenger), work and switch service and the total mileage for all classes; the gross tons one mile for freight service; the passenger train cars one mile; tons per draft; fuel consumed in tons for freight service, passenger service and both; the average price of coal per ton and its total cost; the cost of repairs, divided into ordinary, general, wreck and total; the pounds of coal per 100 ton miles of freight service and per 100 passenger car miles; the miles run per ton of coal in passenger and freight service and per pint of valve oil and engine oil; the cost per mile run in cents, divided as follows: fuel, repairs, wages, oil and waste, stores and total. These figures offer a direct comparison of different classes of engines engaged in the same class of service, making it possible to determine which class or type is the most economical for that service.

The Waste of Energy in Railroad Operation.

By D. C. Buell.

(This paper was read at the 1907 convention of the Traveling Engineers' Association. It is essentially a study of fuel economies, for while some of the matters mentioned may seem foreign to that subject, yet each one is reflected to a greater or less extent on the fuel bill. It serves to emphasize the fact that not only is it necessary for those in the mechanical department, who have actual charge of the fuel, to exercise care and judgment and co-operate with one another, but the various departments—purchasing, operating, maintenance of way and mechanical—must co-operate to secure the best results. The paper is worthy of the most careful thought and study.)

The energy wasted on railroads may for our purpose be divided into three classes:

First—Energy wasted by present well-established systems which, while known to be wasteful, nevertheless appear to be in

Hall 11 07 2M 7937

Form 1133 Standard.

Santa Fe.

(Insert name of Railway Company.)

FUEL PERFORMANCE OF ENGINES OR ENGINEERS.

____________DIVISION MONTH OF____________19____

NAME OF ENGINEER OR ENGINE NUMBER	TOTAL ENGINE MILES	TOTAL TON MILES	POUNDS OF COAL OR OIL CONSUMED	AVERAGE POUNDS OF COAL OR OIL PER 100 TON MILES	AVERAGE TONS HAULED PER TRAIN	TOTAL MONEY LOSS OR GAIN DUE TO PERFORMANCE SHOWN BASED UPON AVERAGE COST PER TON MILE	
						LOSS	GAIN
DIVISION TOTALS							
SAME MONTH LAST YEAR							

____________ Superintendent. ____________ Div. Master Mechanic. ____________ Fuel Supervisor.

Date____________

FIG. 21.—MONTHLY FUEL PERFORMANCE REPORT OF ENGINES OR ENGINEERS, SANTA FE.

some cases the only practical, or, in others, the most economical means to accomplish the desired results.

Second—Energy now wasted by improper systems of management or improper or uneconomical machines or devices of various kinds now in use, these being under the control of officials higher than the road foreman of engines.

Third—Energy now wasted either by improper systems of management or by improper methods of handling or working machines, or the improper condition of the machines themselves, over all of which the jurisdiction of the road foreman of engines extends.

* * * * * * *

Science has proven that the mechanical equivalent of one heat unit (B. T. U.) is 778 foot pounds of work, so that to produce one horsepower for an hour would require power equivalent to 2,545 heat units. One pound of coal when properly burned will give off about 14,100 heat units, or enough to produce five and one-half horsepower for one hour. In locomotive service it takes at the lowest estimate twenty-five pounds of water (steam) per indicated horsepower per hour. Neglecting the loss due to friction of the engine, this would mean that to produce five and one-half horsepower per hour in a locomotive would require 137½ pounds of water, and as one pound of coal evaporates only about five pounds of water in a locomotive boiler, twenty-seven and one-half pounds of coal would be required, that is, only 3.6* per cent. of the actual energy in the coal is realized in this case, the other 96.4 per cent. being energy wasted, due to the method of converting the heat into work.

* * * * * * *

Aside from the method of generating power its use must be considered. The grade line of the road may be such that a very large amount of power is wasted. Possibly a small expenditure on grade reduction would more than pay for itself in power saved. The method of handling tonnage is also to be considered, as when the rating is too light energy is wasted by not using the machinery to its economical capacity, and vice versa; if an engine is overloaded, energy is wasted in slipping, stalling, in doubling hills and due to the much slower rate of speed at which train is moved, which is a controlling factor in considering the amount of energy wasted. The type of steam engine used is a factor also, some roads using very large and powerful engines, others using small power, some with compound locomotives, Walschaert valve gear, superheaters and other devices, all endeavoring to give greater economy and better service.

Each type of engine, valve gear or special device, if it has merit, shows its greatest economy under certain special conditions, and in order to save, rather than waste, careful consideration should be given to the selection of not only the locomotive, but the special devices on it, to insure having a machine that will be economical under the conditions under which it will have to work. The track conditions in a great many cases are such that the friction or train resistance of the cars passing over it is greatly increased over what it would be were the track properly maintained. All increased resistance of this kind, of course, means a corresponding waste of power.

* The Pennsylvania Railroad locomotive tests at St. Louis showed heat efficiencies of from 3 to 8 per cent. for the various locomotives under different conditions.

Form 1449 11-07 15

GREAT NORTHERN RAILWAY LINE.

DAILY BULLETIN OF

PERFORMANCE OF ENGINEERS AND FIREMEN.

INSTRUCTIONS :—MASTER MECHANIC—This form to be filled in complete by Master Mechanic and posted in round house each day.
TRAIN DISPATCHER—Must fill in columns 1, 2, 4, 5, 6, 7, 8, 9, 10 and 11 for each train each day, 24 hours, and forward on first train to Master Mechanic.
ROUND HOUSE FOREMAN—Must fill in columns 1, 2, 3, 6, 12, 13, 14, 15, and 16 for each train each day, 24 hours, and forward on first train to Master Mechanic.
ENGINEER—Must fill in columns 1, 2, 3, 6, 12, 13, 14 and 15 for each run and hand to Round House Foreman at end of run.

Round House__________

						TRAIN			TIME		Consumption Supplies				
1 Date	2 ENGINEER	3 FIREMAN	4 FROM	5 TO	6 ENGINE	7 Number	8 Number of Cars	9 Tons	10 On Road	11 Delay	12 Tons Coal	13 Pts. Valve Oil	14 Pts. Eng. Oil	15 Lbs. Waste	16 Oil Used for Packing of Engines

FIG. 22.—DAILY BULLETIN OF PERFORMANCE OF ENGINEMEN, GT. NORTHERN RAILWAY.

The foregoing cases are what might be called fundamental wastes on a road, that is, they are determined by the physical condition of the road, the class of power and equipment and the fixed policy of the management. There are numerous other wastes, however, that the road foreman of engines is directly interested in and which he can reduce to a minimum. There is a possibility of a large loss of energy due to improper lubrication of locomotives and cars. The subject has been so thoroughly worked up by the different oil companies that there is no question but what the amount of oil generally allowed for an engine or car is sufficient if properly used or applied. A waste of energy will occur, however, if the matter is not properly attended to. Dry valves on a locomotive will make a difference of twenty-five to fifty tons in the train load that can be hauled over the grades, and there is reason to believe that the waste would be greater in proportion on a comparatively level road. Hot pins, eccentrics, driving boxes, etc., cause waste through increased friction of the parts, although the loss of time caused is a much greater and more costly item than the loss through increased friction; the same is true of hot boxes on trains due to improper lubrication.

FUEL DEPARTMENT ORGANIZATION.

The problem of fuel consumption, or better combustion of fuel, is another serious matter. On most roads there is no one man who is held accountable for the amount of fuel used. It would seem that there is room on a railroad to-day for a man whose title might be fuel superintendent, who would have charge of and direct the work now done by the fuel agent, including inspection of coal and the assignment of certain grades of coal to various coaling stations. He would be so closely in touch with the mechanical department that he would be able to advise what class of coal was to be furnished each division point, so that engines might be drafted for the class of fuel to be burned, and he would have on his staff a corps of traveling firemen to see that the men were properly instructed concerning the principles of combustion and were firing their engines according to correct principles, and that the engines were drafted so that they would burn the fuel in an economical manner when properly fired. Such a man should be able to effect a wonderfully large saving when it is considered that to-day the fuel agent in some cases is trying to make a record by buying cheap fuel and will not admit there is such a thing as poor coal. The mechanical department, to avoid steam failures, is drafting engines to handle the poorest fuel, and the men on account of poor coal, improperly drafted engines, or lack of interest, are burning from ten to twenty per cent. more fuel than necessary.

Of other channels through which energy is wasted may be mentioned the following:

COAL WASTED.

Coal not properly inspected at the mines, allowing slack and dirt in considerable amounts to take up space in cars, tanks and fire-boxes that the coal should occupy, to say nothing of the loss caused by dirty fires, clinkers, etc.

Coal spilled at coal chutes and not picked up.

Coal stolen all along the line.

Coal wasted on account of improper or wasteful methods of firing up engines at the roundhouse.

Coal spilled from engine tanks being filled too full.

Coal spilled from engine deck on account of its not being kept clean.

Coal wasted through grates on account of the fireman shaking them improperly.

Coal wasted on account of firing not being properly done.

HEAT WASTED ON ACCOUNT OF:

Ash-pans not properly made for admission of air to give proper combustion or not kept cleaned out.

Engines not drafted right to give proper combustion.

Boilers or flues being dirty.

Steam leaks in fire-box or front end that interfere with the proper combustion of the fuel as well as wasting heat by the leakage.

Forcing the fire too hard, drawing the gases out of the stack at too high a temperature.

Engines not properly lagged.

Heat wasted which might be saved by hollow fire-brick arches, combustion tubes, feed-water heaters or special devices of this nature that have been proven economical.

STEAM WASTED DUE TO:

Valves or cylinder packing blowing.

Cylinders not smooth. That is, where the inside of the cylinder wall has not become glazed so as to reflect the heat and keep it in the cylinder, instead of absorbing it, and radiating it out as a cylinder which is pitted or unglazed will do.

Leaks across steam passages.

Leaks in steam valves.

Pipes or fittings leaking, either on the engine or in the cab.

Improper location of piping or working of the injectors.

Air leaks on the engine or cars.

Steam heat leaks.

Hot water leaks at any point from boiler or fittings.

Steam wasted through the pops on account of the engine not being fired properly.

POWER WASTED ON ACCOUNT OF:

Valves set improperly.

Lack of lubrication.

Improper feeding and firing of the boiler.

Improper running and handling of the engine.

Drafting the engine so as to give excessive back pressure.

Improper handling of the air.

Brakes set up too close.

The waste of time on a railroad is almost always accompanied by a waste of energy because cars, engines and men are lying around when they might be doing useful work.

TIME WASTED AT ROUNDHOUSE DUE TO:

Engineers not making proper work reports. Some one has said that the word "examine," as used by engineers on work book reports, has cost the railroad companies hundreds of thousands of dollars. Get your men to make correct work reports.

Inefficient or insufficient force not getting work done promptly, thus delaying a $15,000 machine for want of machinist or helper.

Sand-house, coal-chute, water tank and cinder pits not properly arranged. If you study your terminal you may be able to suggest some improvement in the layout that can be made at reasonable cost and would save more than enough in the cost of handling engines to pay the expense.

Lack of proper supplies at storehouse, requiring engineers to hunt up foremen and then spend more time robbing other engines to get what they want.

Lack of tools on engines, so that engineers cannot do necessary work promptly. A good locker room where tools, oil cans and overalls can be locked up will save most of this trouble.

Employing a boy who cannot be depended upon to do calling, when a few dollars more a week would pay for a man who would have some judgment and discretion and would save five times that amount in terminal overtime.

Not having a proper record of where men live and can be called.

Not having extra men enough to keep power moving as fast as ready and wanted.

Not having men called in time so they can get ready to go out on their call.

TIME WASTED ON ROAD DUE TO:

Not having proper tools on engines in case anything happens.

Trying to stop an engine at water tank with a long train instead of stopping short and cutting the engine off.

Not having fire in condition to go, after meeting a train or getting orders.

Not oiling around promptly.

Engineer and conductor not working together to make meeting points or figure on station work.

Careless handling of train and pulling out draw-bars and bad order of cars.

Not watching for signals from train crew.

Not having a supply of sand at convenient points between terminals for bad weather or emergencies.

Engines not properly washed out, causing foaming and consequent loss of tonnage or time.

Allowing coal to get in tanks, stopping up injector supply pipes.

Not cleaning strainers in injector supply pipes at frequent intervals.

Water accumulating in main reservoir, thus requiring a longer time than necessary to release brakes.

Not keeping sanding devices in good working order, with result that engine slips badly in starting train or on hard pulls.

Engineer and fireman not working together so they will have steam and water where needed.

Fireman not awaking to the fact that ash-pan needs cleaning until engineer and train crew are ready to go.

Engineer laying down when something goes wrong with his engine when with a little thought and some energy he could have fixed things and brought his train in.

Crew stopping to eat just where it suits them without notifying the dispatcher or regarding the possible disarrangement of his plans.

Engineer or conductor not advising dispatcher if anything is going wrong so they cannot make the time expected of them. This hurts the other fellow at meeting points and maybe ties up the road.

Engineer not willing to admit there is anything wrong with his engine, resulting in long arguments between engineer, conductor and dispatcher, with consequent waste of time. This is due in many cases to the fact that the engineer is "burned up" so badly if he admits an engine failure that he will deliberately say there is nothing wrong with his engine when he knows he could not make ten miles an hour with the train. Do not let your men get false ideas about not admitting there is anything wrong, so the train can be reduced if necessary.

There is a great deal of energy wasted in the yard and on the road directly chargeable to the transportation department, part of the cost of which in many cases falls on the mechanical department. For example, time wasted in not having trains made up, crews ready or the yard open so the engine can get to the train and get out on call.

Indifference in matter of switching coal to chutes, cars of company material to the rip track or roundhouse, switching bad orders to the rip track and pulling and setting rip tracks properly, pulling cinder track, etc. Along this line may be mentioned the seeming delight some switchmen take in blocking the roundhouse leads, so engines cannot get in or out.

There is also time wasted getting bills and orders, all of which is reflected in cost of coal charged against engines and wages of enginemen, etc.

On the road there may be waste due to poor distribution of time on schedules, poor dispatching, slow orders out which should have been canceled, orders put out at points where it is hard to stop and start when some place where train would have

to stop for water or a meeting point could have been used just as well.

Another waste is due to trains being made up improperly, loads behind instead of ahead, empty car doors open, short loads in what is supposed to be a through train, etc.

Slow orders put out by the maintenance department also add to the fuel bill, because unfortunately they are usually necessarily placed on track just at the foot of a grade or on a curve on some hard pull.

Many water tanks are located so that it is up-hill both ways away from them. Of course, the streams are usually found at the bottom of hills, but it is cheaper to pump water to a tank at the top of the hill than to pull the train from a standstill to the same point; stations are located so the train has to be stopped on a curve, and sidetracks so that with a full train the brakeman has to jump off and sprint for the switch, because "if they stopped they would have to double in."

LOCOMOTIVE FIRING.

The possibilities of fuel saving are probably greater after the coal has been placed upon the locomotive tender than at any other point in its journey from the mine to the ash pan. Considering a great majority of the locomotives in this country, which are easily within the capabilities of hand firing, and placing the limit at possibly two tons of coal per hour burned, we know that there is an enormous amount of waste, and in most cases needless waste, going on all of the time.

The qualifications of a good fireman are, first, intelligence or brightness and, secondly, physical strength and endurance. In a great majority of cases no large amount of strength is required for proper firing, in itself, and that factor enters into this problem, the same as it does in all similar lines of activity, only when the action is constant and continued for a long period of time. Even then we find that the best firemen are not usually those who can raise the heaviest weight, but rather the men of moderate strength and great endurance. They are the fellows who fire properly and keep everlastingly at it. Your strong man will handle more coal and work harder; will be exhausted and require a longer period of rest, all because he has performed much useless labor and incidentally has needlessly thrown away a large amount of valuable coal. Comparisons between the small wiry chap, who uses his head, and the big strong fellow, who heaves coal, are present at every division point in this country and almost universally result in the favor of the former, provided, of course, he has been given the proper instruction.

The results that can be obtained from the education of firemen have been most thoroughly discussed in the columns of this and other technical journals, as well as in papers before societies and clubs, but apparently have not been sufficiently impressive to cause the introduction of a practical course on most of our railways. A few of the companies are furnishing their men with literature going more or less fully into the theory of combustion and giving detailed instructions as to the proper method of firing, and still fewer have followed this up with a thorough course of individual instruction, but a very great majority have done neither and practically allow a new fireman to learn his business as best he can from his associates.

On divisions where the proper grade of men can be obtained and the work of instruction is systematically and conscientiously followed out, most gratifying results, in the shape of improved fuel records, increased interest in the work, and a contented and loyal set of firemen, are possible. Upon the other hand where either a low grade of men is all that is available, or where the work of instruction is done in a half-hearted or slip-shod way by incompetent instructors, the education of the firemen is bound to be a failure in all ways. There will always, of course, be individual cases that it will be impossible to do anything with. These will usually be found to be confined to the man with a strong back and a weak head (which some one has facetiously stated should be the qualifications of a fireman), who can get over the road because of his strength, but cases of good firemen quitting because they could not stand the work, which was easily within their strength if they had been properly instructed, are not by any means uncommon throughout the country, and it is this feature that causes the greatest regret that more attention is not being given to the subject of education. If you cannot get firemen of sufficient intelligence it is unfortunate, but if you don't keep those who are capable of learning, there is certainly a grave fault somewhere.

The lines that should be followed in educating the firemen are covered in a general way in a previous section of this article. As far as the actual placing of the coal on the fire is concerned they consist very largely in convincing the men, both by sound reasoning and actual example, that it will pay, and pay well, to scatter well broken coal in small amounts on various parts of the grate in succession, with such an interval between charges as will make it necessary to again cover the first point as soon as the whole grate area has been gone over. This, of course, with the ordinary locomotive, means continuous, but in most cases leisurely, work and gives no time for the seat box or anything else while the locomotive is working at full power. Opportunities for the needed rest will be given on the down grade stretches, the stops for water, the waits at meeting points or for orders and the shut-offs for signals, flags, etc. This is the way firemen should fire and the way an intelligent educated fireman will fire *provided* he is not expected to take care of ten or fifteen other things at the same time. He cannot and will not do it if he has to break all of his coal; if he has to climb up and shovel it down from the back of the tender every half hour or so; if he is expected to see every signal; if he has to clean out the ash pan at every stop for water; if he has to work against an injector that "forgets" or a couple of extra notches on the quadrant; if he is given dirt and slack for coal; if the competitive coal records are based on the guesses of an ignorant coal chute hand; if the records are posted six weeks after they are made; if an engine rated at 2,000 tons is habitually given 2,200 tons, etc., etc.

The education of firemen will pay if it is given a chance, but there is no use in teaching a man to do a thing properly and then arranging conditions so that it will be impossible for him to do it that way. Give a fireman a small shovel, not over 15 lbs. capacity, an automatic door opener and decent coal; teach him how to fire and if he is not loaded down with other duties and handicaps you will be surprised how little coal he will burn per ton mile or per car mile, as well as in the reduction of engine failures due to leaky flues and fire-boxes.

Of course there are many conditions affecting the efficiency of the firemen over which the motive power department has no control, and many others over which no one has control, all of which tend to neutralize the value of the properly educated fireman. But there are enough which can be controlled to make it very advisable to accompany a scheme of training firemen with a course of education and improvement along other lines. It is not an impossible condition to find master mechanics and even higher officials who are in need of a little educating in things which directly concern the firemen and the fuel bill.

There is one condition, however, which no amount of training or education will improve, and that is a locomotive of a size and power which no man can shovel coal enough into, properly or improperly, to develop its capacity. This would also include those locomotives which are capable of hand firing, only when everything is in perfect shape, and fall down under ordinary adverse conditions. At the present time there is no very large number of locomotives running in this country which would come strictly under this head and if we had only to consider these, there would be no great demand for mechanical stokers. There are, however, a large number of big engines which, from causes beyond the mechanical department's control, and seemingly incapable of correction, a few of which have been mentioned, are not able to give their full power with hand firing.

At some points it is impossible to get men for firemen who are of a sufficiently high order of intelligence to be able to learn to fire properly and economically. This may be due to a poor source of supply; to a rush of business compelling the acceptance of any one, or to working conditions and surroundings, which no self-respecting man will put up with. No matter what may be

the cause of their presence such men will not be able to develop the full power of a big locomotive over a division of average length.

Again it may be very desirable, and possibly profitable, to use a grade of fuel which is so high in ash and impurities as to compel a man to get it into the fire-box as fast as he can, so as to have time to shake the grates. He certainly cannot properly develop the power of the locomotive under these conditions, even if the fuel is capable of doing it at all.

Thus there are four conditions which are beyond correction by the proper education and training of the firemen, and even beyond correction by the mechanical department. These are,—very large locomotives; operating conditions making proper firing impossible; low grade of men and use of low grade fuels. Under such conditions we are compelled to look to a mechanical device if we are going to get out of our locomotives all that is in them for the whole length of a long division.

There are also many conditions which seem to indicate a pressing need for the mechanical stoker, but which are within the control of the mechanical department, and can be solved much better in other ways. These have been touched upon more or less fully above.

For the purpose of getting an idea of the actual state of affairs in respect to how general and insistent a demand for mechanical stokers exists, a letter was sent to about seventy-five motive power officials asking their opinion on the subject, and the reasons therefor. The letter also asked for an account of any experience that they may have had with mechanical stokers.

The answers as a rule were perfunctory and indicated that while a large majority thought a mechanical stoker was badly needed, the conditions were not serious enough to cause any special efforts being made to alleviate them, in any other way, while awaiting the perfection of a satisfactory stoker. Quite a number had given the subject more careful study and basing their deductions on the conditions existing on their own lines arrived at some very sensible and definite conclusions.

One motive power official who is well known for his clear-cut opinions on big subjects, writes as follows:

"As far as we are concerned we do not at present feel the need of the mechanical stoker on locomotives, unless its adoption should result in a general and substantial saving in fuel. It is possible that the application of a mechanical stoker to all our engines might do this, but my feeling is that the mechanical stoker can at present only represent average good firing and while it might give superior results to a poor fireman it could hardly be equal to the best.

"The question, however, arises as to whether the same amount of money spent in educating our firemen and following the matter up closely would not give equally as good results as the adoption of the mechanical stoker and possibly as good results could be obtained without as much money being spent. Anything we add to the locomotive, while it may appear simple and substantial, will ultimately mean expense for maintenance and occasional trouble from failures, and unless some real advantage is going to be gained from its use it will be a very questionable device to go into.

"While we have tried the mechanical stoker we have not so far had much success with it but I do not consider that the small number used has much to do with the stokers not working satisfactorily, but more on account of attention to the stoker not being worth the trouble when all things are considered.'

An answer from a road which burns oil on some of its divisions and hence has been able to observe the result of comparative idleness on the labor situation is in part as follows:

"What does the railroad gain by going to the expense of installing stoker equipment when already firemen are being paid (enough surely) to do this work? It has been my observation in a general way that only those men whose time and whose efforts are pretty fully taken up actively, are contented and would produce the best results. As an instance I may cite the case of firemen on coal burning locomotives as compared with firemen on oil burning locomotives: the former have to do a fair amount of pretty hard work to hold their jobs and the troubles in dealing with these men are due chiefly to the fact that most of them are quite young and have the rash impetuosity and hot headed devil-may-carelessness of youth; the latter has practically nothing to do but to sit on his spring seat cushion, occasionally touch the valve levers controlling the fuel oil, air, and steam supplies, and semi-occasionally funneling a little sand through the fire door for the purpose of scouring out carbon and sediment deposits in the flues—he does not have to work so hard nor be so skilful as the engineer, and in fact has practically nothing to do but gaze out upon the burning desert wilds and think of his troubles. As a class, the oil-burning firemen are overpaid, are discontented, giving unsatisfactory service, are grossly wasteful of fuel and ready to seek any excuse to shirk some portion of their duties; and their agitators and committees give constant trouble.

"Would not the general application of the mechanical stoker, with its relief to the fireman of the only real work he is called upon to do, similarly serve to produce an unsatisfactory labor condition? The coal firemen have to work so hard that only the fittest and most persistent can stay by the job; in this way we get a pretty good type of manhood for filling the later responsible positions as engineers; would this be the case if physical prowess was no longer a requisite for fireman's service?

"Would the mechanical stoker give economy in fuel? I doubt it just from such examples of automatic stokers applied to stationary practice as I have seen. The mechanical stoker would be apt to give considerable trouble in repair and attention and I venture to say that it would add another fruitful source to the many producing engine failures. These repairs, moreover, would probably be quite costly at the year's end, taking ordinary railroad conditions as the criterion.

"In general, of course, the question of fuel is a very important one, in fact it is the most important consideration of all our immense industrial life and it is the largest single item of expenditure making up the cost of operating American railways, amounting, as it does, to approximately 10 per cent of the operating expenses. It is not too much to say that if this matter was followed up very carefully, and practically perfect conditions of combustion were secured, on each and every engine of a railway, the total cost of fuel could be reduced one half.

"While I would regard the mechanical stoker as not practical under ordinary American railroad conditions to-day, I do believe that such a device would have a limited field of usefulness as applied to some of our very largest engines in the very hardest service, *e. g.*, pusher engines of the Erie Mallet type (which now require two firemen)."

Two roads running west from Chicago reply as follows. One of these has a large number of "big" engines in both passenger and freight service. The other does not use very large locomotives in either service.

"I do not regard the need for a locomotive stoker as particularly urgent as we find it possible to get along pretty well without it. The stoker question is attractive however to some railroads which find it necessary to burn inferior grades of coal, which might be burned more satisfactorily by the use of a stoker."

"With the size of locomotives in use on this road I do not believe there is any real necessity for a locomotive stoker, although probably on some of the larger power this may be necessary. As I understand it, the men the stoker was designed to benefit are the principal objectors to using it, and where it has been tried it is my information that they have been the means of knocking it out. This is only hearsay, but I believe it is correct."

Replies from two Southern roads indicate the poor grade of labor in that section creates a demand for mechanical stokers which would not be present on the same locomotives in the Northern States:

"With the large modern engine and the work that is required of it, we have about reached the limit of human endurance in firing a locomotive, and it would be extremely desirable to use a mechanical stoker, if it was possible to design one that would deliver the coal to the grates in proper quantities and properly distributed. So far as I know, the reason that stokers are not generally used is due to the fact that as yet there is not a stoker that will do the work properly. We made quite an extended test of two stokers on our lines, under the personal supervision of our road foreman of engines and our engineer of tests and were unable to accomplish the desired results. The Pocahontas coal which we use is a very high grade coal, and it is my opinion that if these stokers would not work with that grade of coal which we are using, it cannot be expected to give satisfactory service from the average grade of coal furnished to the various roads of this country."

"I am thoroughly convinced that a mechanical stoker for locomotives is desirable. In the first place the size of our engines is such that it is almost impossible to obtain firemen of the requisite intelligence for handling them; the only class of labor that we can obtain, on account of the extreme drudgery of the work, is such as lack the intelligence to develop ultimately into suitable engineers."

Other interesting opinions from various sections of the country are given below.

From a road in the middle South:

"With wide fire box engines it is our observation that the mechanical stoker is not needed, as we find that one man can fire an engine hauling 4,000 tons of freight over a 120 mile division with a wide fire box, where it is out of the question for him to do so with a narrow and long fire box—all other dimensions of the engine being the same."

From a road running east from Chicago:

"I believe that there is a need for a mechanical stoker on locomotives, especially is this so in warm weather. We had quite a number of locomotive firemen on our large consolidation engines overcome with the heat last summer. We believe a good design of mechanical stoker would avoid this, as well as show an economy in the consumption of fuel.

"Our experience, with stokers tested, indicated that there were two objections: One, mechanical defects in the stokers causing them to fail: the other, the mechanical stoker which we had experience with occupied

practically all the room on the deck and had to be removed on each failure in order to hand fire the engines. This stoker when in good working order would fire any locomotive we had on our road and would do it successfully, and we believe more economically than the firing could be done by hand. But for the reasons named and the further reasons that we only had a half dozen of them in service we could not get as satisfactory service under these conditions as we could with hand firing. I would suggest that where mechanical stokers are introduced that they be applied to all the engines on the same division.'

Another road in the middle West:

"During the past four years the scarcity of labor has made it very apparent that there was necessity for some proper device for feeding of coal in fire boxes of locomotives. In a great many cases it has been necessary for railroads to employ firemen who were not of a satisfactory weight or intelligence to handle the work required of a fireman on our modern type of locomotives and from whom we could not expect to get competent enginemen. The work of the firemen is becoming so arduous on the larger type of locomotives that any man with any degree of education will not seek this class of employment, but goes into other channels where the duties required are less taxing on their strength and for which they get a better return. As a result of this condition we must expect a natural decline in the quality of our enginemen and in view of the above facts I feel that the necessity for a satisfactory stoker is very apparent."

A road running out of Pittsburg states:

"We have never used mechanical stokers and at this time hardly think they are a necessity, but as engines increase in size they are bound to be, and it would seem to me that the production of some efficient stoker should be encouraged as much as possible."

A far Western road replies:

"We do not believe that there is a very urgent need for stokers as our firemen are able to handle our present locomotives without any trouble."

From a Southern system:

"There is at present in this country the most urgent need for a reliable mechanical stoker on locomotives. The rapid development of heavy power has made the duty of the locomotive fireman so exacting that we find it very often to be the case that the man is unequal to the duties imposed upon him. Railroads must perforce recruit their engineers from the firemen's ranks. For this reason it is necessary that the firemen be men of some brain, as well as brawn. Of course the strong mind and the strong back may be sometimes found together, but it is a little bit unusual, and the strong mind is not hunting—as a general proposition—for such laborious occupations as locomotive firing has become. I am aware of instances of heavy power being run in this country under tonnage rating, for the reason that one fireman cannot maintain the maximum steam pressure and handle full ratings on the schedules involved."

From a road running west from Pittsburg:

"The necessity for a mechanical stoker for locomotive purposes is urgent, and while saving in fuel is, of course, an important item, if a successful stoker is developed and no fuel saving effected, the demand for its application is still urgent.

"1st. On account of smoke ordinances which all of the large cities are enforcing, which may compel the railroads to use a very expensive fuel. The uniform firing with a mechanical stoker will greatly reduce, if not entirely overcome complaints on account of smoke.

"2nd. In the selection of firemen to-day, on account of the more arduous character of the work, we are practically hiring a man on account of his capacity for physical endurance. The mechanical stoker, by reducing the requirement on this account, should enable us, to some extent, to pay more attention to intelligence.

"3rd. A successful mechanical stoker should reduce to some extent flue leakage troubles.

"4th. It should permit the use of commoner and cheaper grades of fuel.

"5th. The possibility of saving in fuel."

The chief lesson that can be drawn from these letters is that, whether there is an actual need for stokers or not, there is, beyond doubt, a demand for them.

Mechanical Stokers.

As is stated in one of the letters above, all that can be expected of a mechanical stoker is to equal average good firing. It cannot be expected to equal the best hand firing, but must, of course, do better than a poor fireman. This, however, is but one of the conditions which a successful mechanical stoker must meet, although of course it is the most important, but a stoker which is to receive general adoption must also possess a number of other very important features. In the first place it must be absolutely reliable. No railroad company can afford to put anything on its locomotives which has any possibilities of causing an engine failure. Again, a satisfactory stoker must be comparatively noiseless. There is already sufficient racket in the cab of a locomotive to make communication between the engineer and fireman somewhat difficult and it will not do to increase this to any appreciable extent, and thus make such communication practically impossible. In addition to this any great addition to the noise on a locomotive is going to make it extremely difficult for an engineer to hear torpedoes. Another desirable feature is that the stoker should take up as little room as possible. It should further consist of the fewest possible number of parts and have no delicate mechanism. It should also be arranged so as to permit a quick and easy change to hand firing in case such a move becomes necessary.

In addition to these strictly mechanical qualifications a stoker must be able to show a direct saving which will at least pay the interest on its cost, a liberal rate of depreciation and all charges for maintenance. Such a saving can be made in several ways, either by improved combustion, leading to the use of a smaller amount of fuel; by the use of a lower grade fuel, due to the stoker's ability to fire properly; to the opportunity of operating large engines over divisions of a length which exhaust a good fireman and lead him to waste coal by improper firing on the latter end of his run; by the reduction of leaky flues and fireboxes directly due to the proper firing; to the reduction of the smoke nuisance in large cities, owing to the better condition of combustion and possibly also the ability to hold a better grade of men.

While practically all of the designs of mechanical stoker, which have so far been given practical trials, have sought to simulate hand firing, accomplishing this by several different methods, there are designs now in the process of evolution which seek to accomplish the desired result in other ways. One of these is an underfed type in which the coal is forced up from below and is burned by means of the forced draft; this permits the elimination of the vacuum in the front end and thus a considerable reduction in back pressure on the cylinders. This type of stoker is claimed to be capable of burning very low grade fuel, giving practically complete and smokeless combustion.

Another arrangement which has been suggested, and is being worked out, which also presents possibilities for use of extremely low grade fuels, is a stoker, in which the fuel is pulverized and blown into the fire-box through a jet, burning much the same as oil. Properly arranged this stoker should be able to give practically perfect combustion.

Both of these types, however, have not yet reached the stage at which their inventors are able to report anything more than bright prospects.

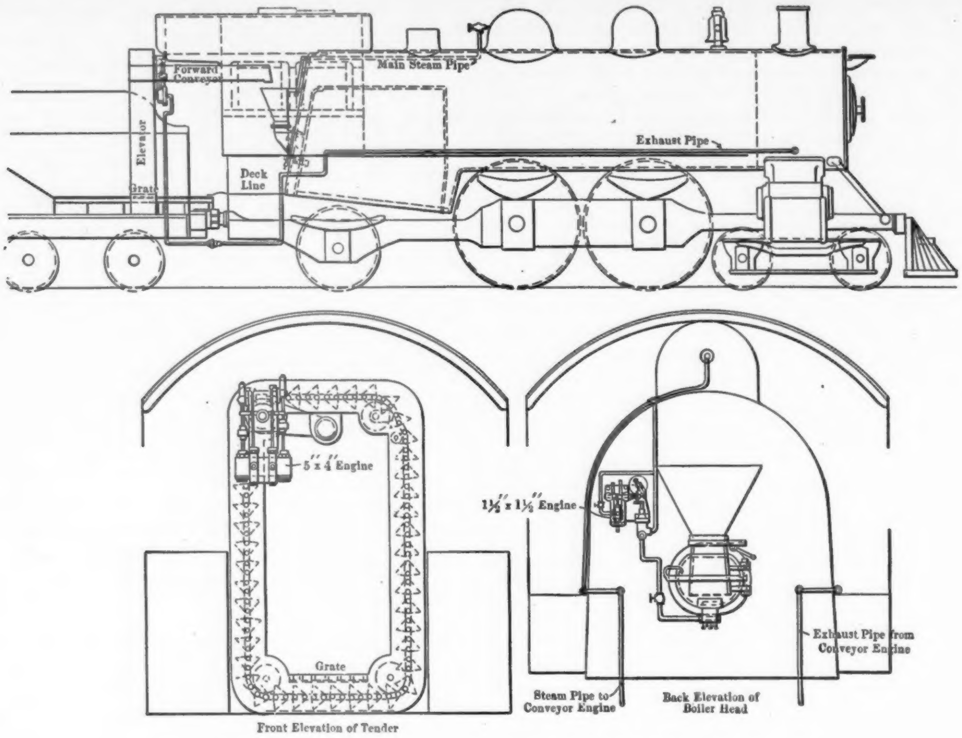
The stokers which imitate hand firing can be divided, roughly, into three different types, one in which the coal is thrown on the different parts of the grate by means of a plunger, a deflection plate being used to govern the direction. Another blows the coal to different points on the grate by means of air or steam jets and the third type uses a revolving fan arrangement, the wings of which throw the coal through a spout, which is capable of adjustment to determine the point on the grate which shall be reached.

In all of these types the principles of correct hand firing are followed out, that is, that a small amount of well broken coal is scattered in either a thin layer over certain separate sections or small pieces miscellaneously over the whole area of the grate. In the former case the different sections are covered in succession, with such a time interval as to make the action of the stoker continuous while the engine is working at full capacity. The best examples of each of these types incorporate a conveyor from the tender to the hopper, forming part of the stoker proper, thus permitting the fireman to devote his entire time to watching the condition of his fire, shaking the grate, and assisting in keeping a lookout ahead.

There is one design of each of these types which has proven itself to be successful in practical service, and while not even the designers claim that perfection has been reached, still we have three designs of mechanical stokers which have proven themselves capable of properly firing locomotives now in service in this country, each being designed on a different principle.

HAYDEN MECHANICAL STOKER.

This stoker is of the type wherein the coal is blown in small amounts on to the grate by means of a steam jet. It has proven



DIAGRAMS SHOWING APPLICATION OF HAYDEN MECHANICAL STOKER.

itself to be thoroughly practical and has been in service on one locomotive on the Erie Railroad for about a year and a half. The construction of the device is clearly shown in the illustrations, from which it will be seen that the fireman is relieved of all hard labor and that when the stoker is once set properly it is practically automatic, while the operation of the locomotive remains the same.

The stoker proper is accompanied by a conveyor which is mounted upon and forms part of the locomotive tender. This conveyor is of such a size and shape that it can be placed between the water legs of the tank with the lower part flush with the bottom of the coal space. It consists of a series of buckets mounted on an endless chain surrounded by a casing. The travel of the buckets lifts the coal and dumps it into a horizontal trough, which extends inward to the hopper on the boiler head. This trough is of a sufficient height to clear the head of a man working underneath and carries a spiral conveyor. The coal inlet at the bottom of the bucket conveyor is covered by a grate having openings 3 in. square. The coal is raked into these openings and is carried by the buckets across and up the right side, then horizontally to the trough, where it is automatically dumped and the empty buckets descend on the other side. The conveyor is driven by a small duplex steam engine mounted on its casing and controlled by a throttle valve on the engine.

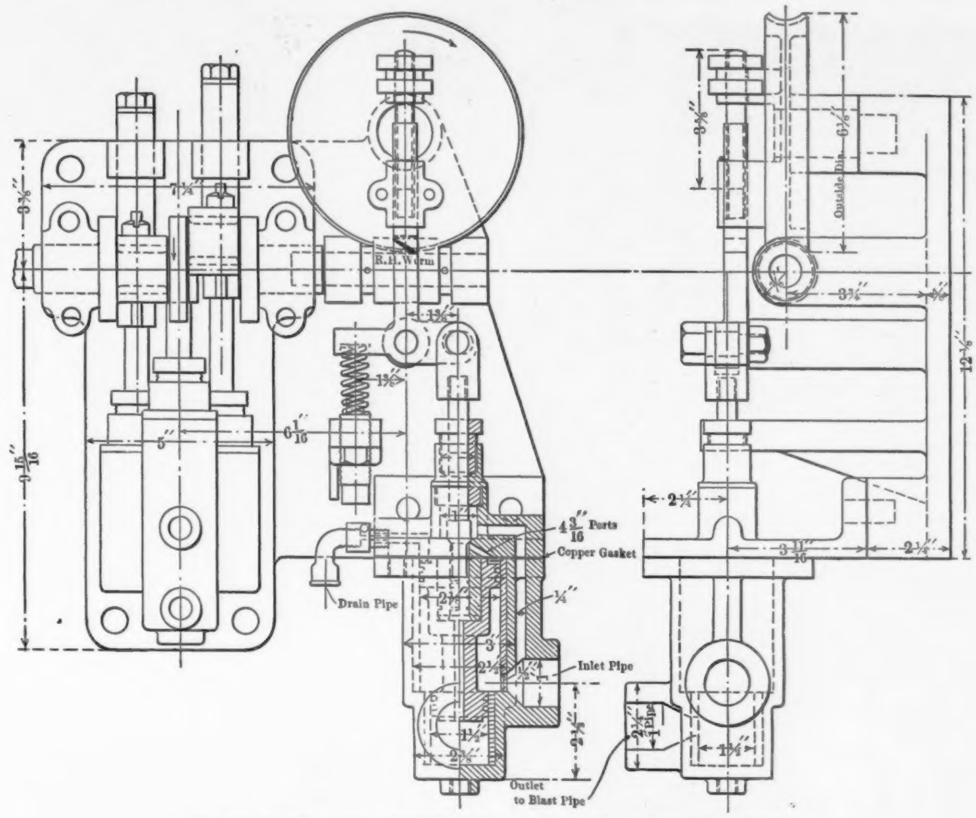
The stoker proper is composed of a narrow shelf bolted on the inside of the fire-box level with the bottom of the door opening and protected by a carborundum facing on the bottom and sides. The ordinary fire door is removed and for it is substituted a door having a chute leading through it, with its upper edge projecting over the shelf just mentioned. An adjustable plate by which the size of the opening can be varied is provided. This door is hinged to the frame in the usual manner and can be opened for hand firing if desired. A hopper which receives the coal from the spiral conveyor is bolted to the boiler head above the door opening and discharges directly into the chute in the door. A sliding gate operated by a rack and gear by which the supply of fuel can be cut off or adjusted at the hopper, is provided. There is no connection between the hopper and the door.

A blast pipe, consisting of a series of jets, is placed in the bottom of the fire door opening on the level with the top of the shelf and the jets are directed in such a manner as to throw the fuel to all parts of the grate. Each jet is provided with a valve, so that the flow of steam through it may be regulated independently of the flow through the other jets. These jet valves are mounted on a manifold that is connected by a pipe to the blast valve. A globe valve in this pipe controls the force of the blast as a whole.

Instantaneous opening and closing of the blast is required, and the blast valve, which is shown in detail in one of the illustrations, is constructed so as to obtain this result. It consists of a main valve, an auxiliary valve and the proper ports combined in a casing so that a slight movement of the auxiliary valve will instantly operate the main valve through its full movement. The manner in which this is done is clearly evident from a study of the illustration. The auxiliary valve is connected to a bell crank, which is tripped by a finger carried on a revolving disc, which in turn is driven by a worm revolved by a small engine which can be throttled to give the desired speed for the number of blasts required.

The operation of the device is as follows: The fuel which is fed into the hopper by the conveyor flows by gravity through the chute in the door and rests in a pile on the shelf in front of the jets. The size of this pile of fuel is determined by the position of the plate at the mouth of the chute. The fuel being fed continuously through the hopper and chute forms an air seal and preserves the draft in the furnace. The jet valves are throttled so that when the blast operates, the fuel is thrown to all parts of the furnace and scattered evenly over the fire. The intensity of this blast is dependent upon the draft conditions in the furnace. The duration of the blast is controlled by means of an adjustment of the trip finger, which operates the auxiliary valve by means of the bell crank lever and thus holds this valve open for a varying period of time. The usual period of blast is about one second. The speed of the conveyor engine determines the amount of coal that is fed to the hopper and can be varied to suit the conditions. For very light firing the stoker is able to place two or three pounds of coal at one charge as often as may be desired, and for ordinary heavy firing it can place ten pounds of coal per charge with a blast of from 1½ to 2 seconds duration, operating seven times a minute. If desired, the blast can be made continuous and as much coal as the conveyor will deliver can be put on the fire. This condition of course is beyond the requirements of any service.

This stoker is manufactured by the N. L. Hayden Mfg. Co., Columbus, Ohio.

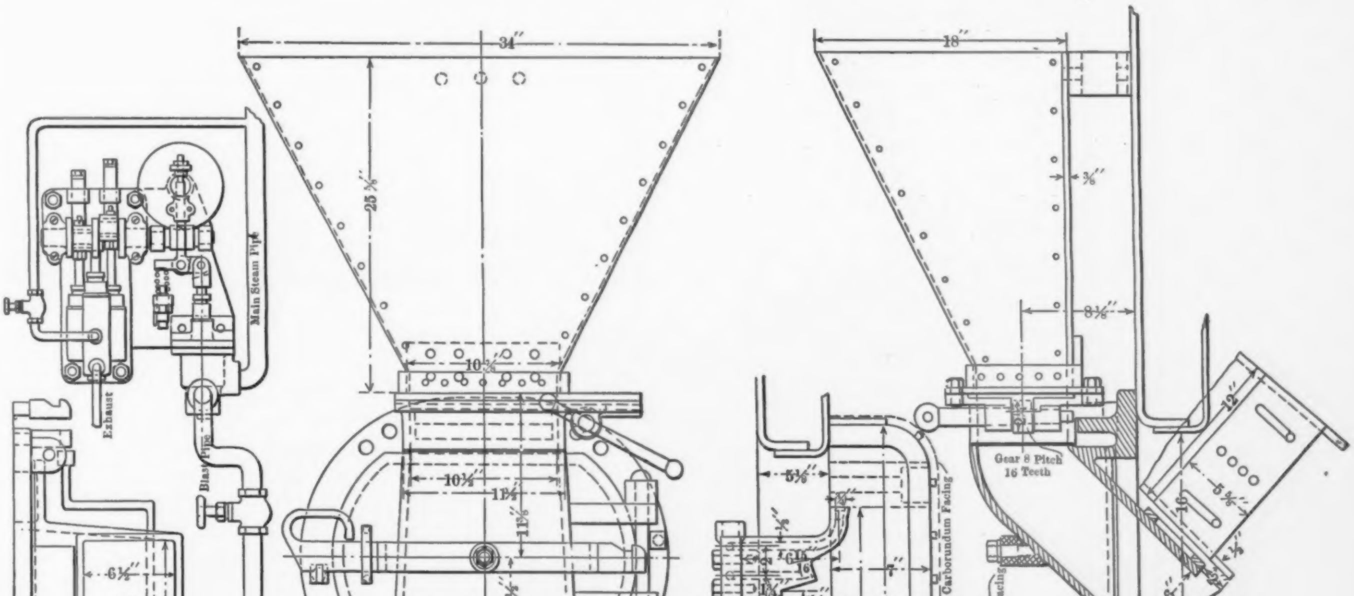


BLAST VALVE AND ASSOCIATED APPARATUS—HAYDEN STOKER.

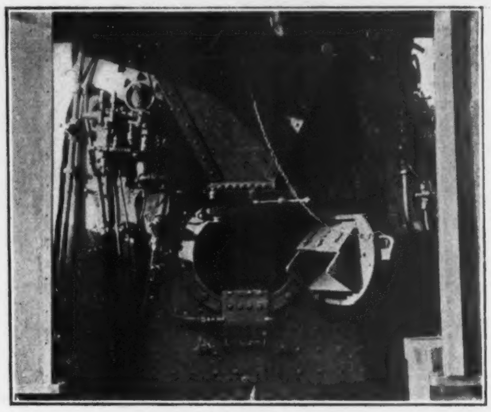
CROSBY MECHANICAL STOKER.

This stoker is of the revolving fan type, in which the coal is thrown into the furnace by means of the wings of a fan and is located by the automatic adjustment of the chute on the inside of the fire door, which directs the coal to the point desired. For the purpose of description, it can be divided into three separate parts: the first consisting of the apparatus which carries the coal from the tender to the stoker proper; the second, the propelling apparatus which forces the coal into the fire-box, and the third, the guide chute which directs the stream of coal to different points on the grate.

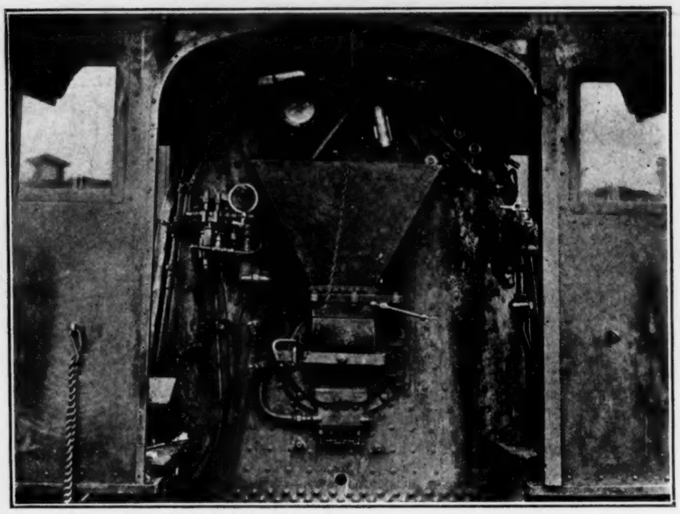
The first step is obtained by means of a screw conveyor extending from the rear of the coal space in the tender to the fire door and running in a sheet metal trough with a circular bottom and flaring sides. This conveyor is in two parts, one section extending from the back of the coal space to a point just in front of the coal gate, where both the spiral and the trough are joined to the inclined section, in a manner which provides perfect free-



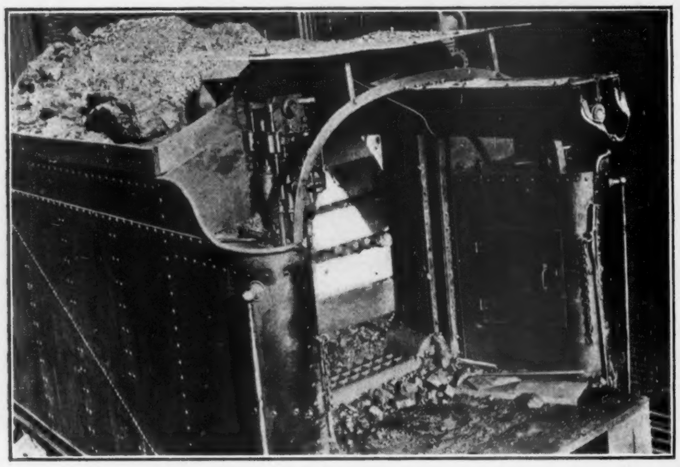
ARRANGEMENT OF BLAST PIPES, CHUTE, HOPPER, SHELF, ETC.—HAYDEN MECHANICAL STOKER.



HAYDEN STOKER—CHUTE INSIDE FIRE DOOR.



HAYDEN STOKER WITH CONVEYOR REMOVED.

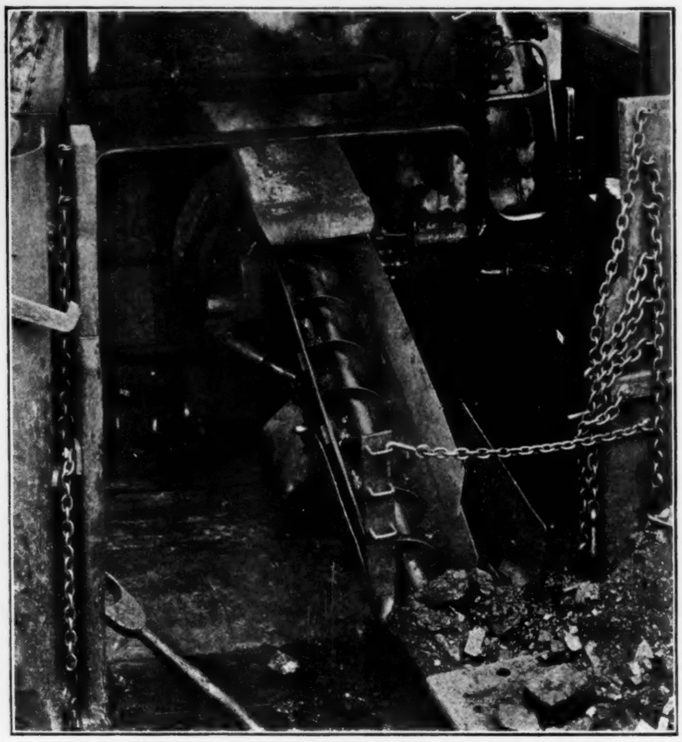


CONVEYOR ARRANGEMENT ON TENDER—HAYDEN STOKER.

ness for adjustment to the relative movement between the locomotive and tender and also to allow the inclined section to be thrown back against the coal gate when not in use. The section in the bottom of the tender is covered from its rear end to within a few inches of the coal gate by plates about a foot long. These plates are removed one by one as the coal pile gets further back in the tender. This conveyor is driven from the same source of power as are the revolving blades, but is provided with a cone gear arrangement which permits it to have a variable speed. A lever, conveniently placed, controls the speed or the starting and stopping of the conveyor by the fireman. The gears are enclosed in a case, which will be noticed in the diagrammatical view as hanging beneath the inclined section.

The conveyor will handle lumps of coal up to about 10 or 12 in. in size, bringing it up to where the fireman can conveniently reach it and break it up into small pieces with an ordinary machinist's hammer.

The conveyor discharges the coal into a small receiving hopper, where the rapidly revolving blades gather it and discharge it through a round nozzle in the door. These each discharge one-half of the receiving hopper, being offset for that purpose, and run at a constant speed while in operation. The receiving hopper forms part of the casting, which is bolted to a specially designed door, replacing the regular fire door. Alongside of it is a steam tight chamber in which is mounted a steam turbine disc upon which four small steam jets impinge. The turbine wheel and rotating blades are mounted on one shaft, which at the turbine end projects through the bearing and carries a fly ball governor mechanism, which operates the steam valve and provides an automatic constant speed arrangement for the blades. The opposite end of this shaft projects beyond the case and carries a worm which drives a worm gear, all being contained in an oil tight case bolted to the frame. The worm gear shaft provides the motion for the screw conveyor. It also, on the opposite end, carries a small worm meshing with a gear, which further reduces the speed and drives the mechanism controlling the motion of the spreading chute, which directs the stream of coal in the fire-box. This small worm may be engaged or disengaged from the shaft by a small lever and thereby stop the spreader at any point in its cycle and build up the fire where it may need special attention.



GENERAL VIEW OF CROSBY STOKER READY FOR SERVICE.

The spreading arrangement automatically passes through a cycle

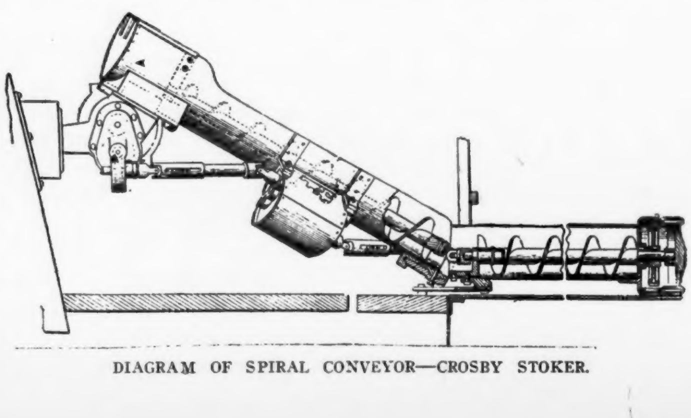
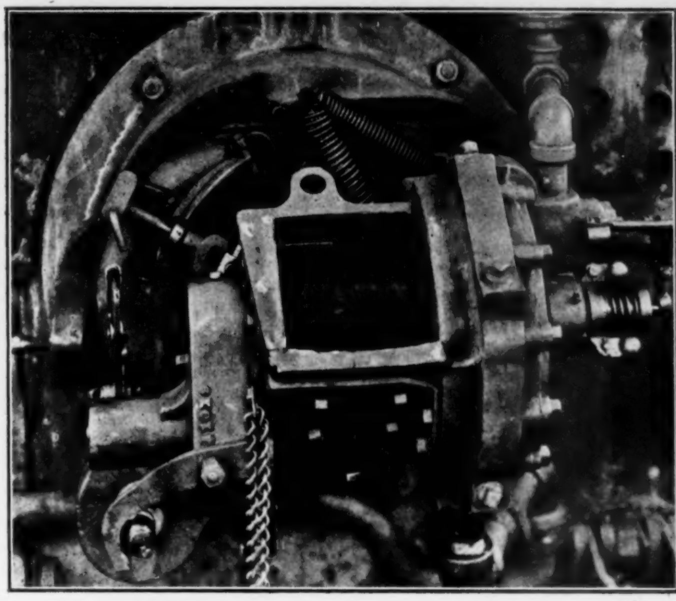
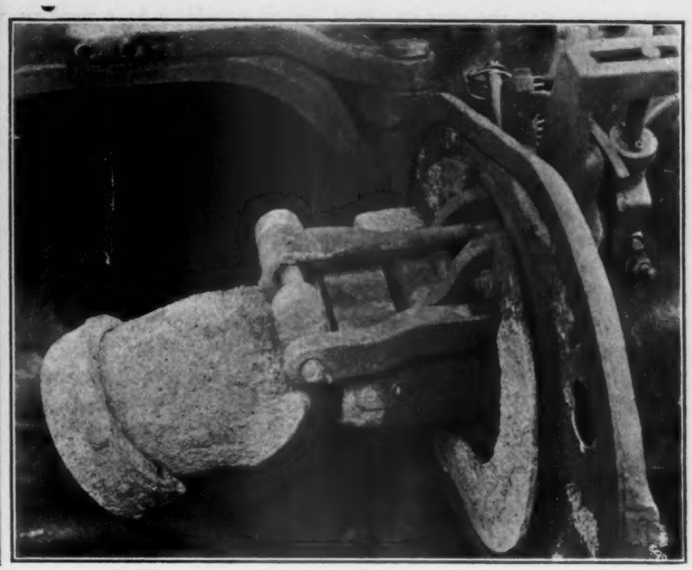


DIAGRAM OF SPIRAL CONVEYOR—CROSBY STOKER.



CROSBY STOKER—APPARATUS ON FIRE DOOR.



SPREADING DEVICE—CROSBY MECHANICAL STOKER.

of movements which accomplish the following results: The thin stream of coal issuing from it is distributed in a thin layer over a strip one-third of the width of the fire-box down the left side, starting from the flue sheet and extending back into the back corner; then with a quick movement the spreader starts at the flue sheet in the center of the fire-box and distributes coal over the center one-third of the width; then quickly moves to the front right corner and down the right side, including the back corner, then transfers again to the front left corner and repeats the cycle. This motion is entirely automatic, but can be interrupted at any point, as above mentioned.

In case of necessity this stoker can be disconnected and put out of the way and permit hand firing to be started in the usual manner within a space of thirty seconds. The total weight of the stoker and conveyor is about 900 lbs.

The work of developing this stoker was all done on the Chicago & Northwestern Railroad, where it, after a certain series of preliminary experimenting had been completed, showed itself to be entirely reliable. It is being built by the International Stoker Company, 181 La Salle street, Chicago.

STROUSE MECHANICAL STOKER.

This stoker is an example of the plunger type, being an evolution from the pioneer locomotive stoker which was known as the Kincaid. It, of course, differs from that design in practically all its features, but is built on the same general principle. It consists, briefly, of a horizontal plunger mounted in guides and operated by a steam cylinder. This plunger carries at its forward end a special shaped nose, which is arranged to discharge the coal on different parts of the grate, depending upon the speed with which it is operated. The forward stroke of the plunger throws the coal to the center, or the front ends of the grate, and the backward stroke, by means of a special shape of the nose, places the coal in the back corners and beneath the fire door.

The coal is discharged into a large hopper by means of the conveyor, which is not shown in the illustration, from which it falls upon a shelf directly in front of the plunger nose. The fire door opening is provided with a specially designed door, hinged at the top and forced open by the plunger on its forward stroke. The whole apparatus, except the special fire door, is mounted on a framework, supported by small wheels, which is secured to the fire door ring by two slotted lugs with keys, and also by two suspension turnbuckle rods, which hook into eyes on the boiler head.

The length and intensity of the stroke of the plunger are governed by levers, shown at the left side, which are operated by the fireman.

This stoker has been applied to a number of locomotives on the Iowa Central Railroad and is manufactured by the Locomotive Stoker Company of Chicago.

BRIQUETTING.

The possibility of obtaining a most satisfactory and high grade fuel for use on locomotives through the medium of briquetting grades of fuel which are now of no practical value, and are usual-

STROUSE MECHANICAL STOKER IN POSITION IN CAB.